

Electronically Modulated Materials: Effects and Context

by

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Bachelor of Architecture
New Jersey Institute of Technology, 1999

Submitted to the Department of Architecture
in Partial Fulfillment of the Requirements for the Degree of

Master of Science in Architecture Studies
at the
Massachusetts Institute of Technology

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Department of Architecture, May 19, 2004

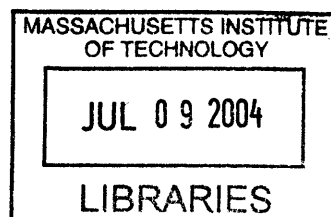
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ABSTRACT:

Recent advancements and increased availability of technologies have led to the design of surfaces and materials that can encode physical properties into digital information that can be manipulated at will. While research at the nano and micro scales continues to develop new materials, the availability and improvements of microcontrollers in recent years has allowed designers to become involved in the developments of human and macro scale physical-digital surfaces. In this thesis I will develop a set of aesthetic issues and attempt to show examples of how I tackled those issues through a series of projects in the domain of physical-digital surfaces. These projects will range in scale and level of refinement from design proposals to working prototypes.

The set of aesthetic issues developed for this thesis will contextualize the surface studies that I have been working on within an art historical context and also suggest areas for further investigation and experimentation.

Thesis Supervisor: William Lyman Porter

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Fig 1: Jacquard Loom and Jacquard Loom Card. Invented about 1800. (A Computer Perspective, 92)

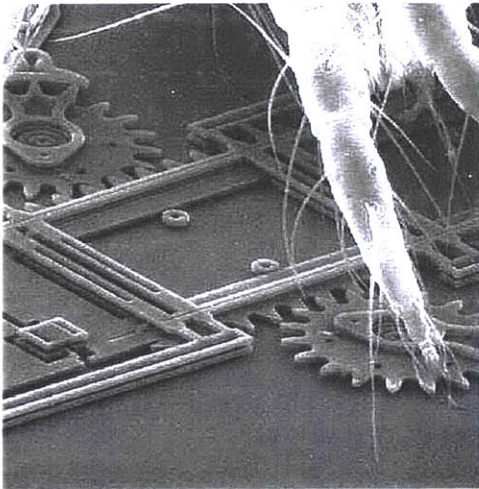


Fig 2: Mirror Mechanism with a Spider Mite, MEMS research.

Introduction

The invention of the Jacquard loom is often sited as a starting point of modern computation. In this loom punch cards are used to control the machinery that creates the weaving. The physical actions of the loom and the physical form of the woven material are recorded into binary data that can be replayed or manipulated at will. During the 20th century the digital technology that this spawned grew ever more sophisticated in its abilities to store, manipulate, and display data on screen. In last 20 years the manipulation of physical form within the manufacturing process has also grown more sophisticated with the integration and availability of CNC machines.

This has led to research into the possibilities of using digital data to manipulate physical material properties in real time. Much of this research is happening at the nano and micro scale as scientists work on problems of assembly and control at such sizes. Another, more accessible way to manipulate physical properties is at the human and macro scale. What has changed is the availability and processing power of microcontrollers, these computers on a microchip have become more inexpensive, easily programmed, and networked .

There are a number of examples of physical-digital surfaces that have been created/prototyped with designers (as opposed to engineers) driving the process. These materials alter elements of their physical properties through electronic manipulation. While the ability to display data or moving images places these surfaces in the realm of display technology, their physical properties set them apart from most digi-

tal technology and make up for their inefficiencies and lack of resolution. Unlike a projection or light emitting screen, when we view these surfaces we see changes of their physical properties, not a representation of changes in properties. When we are looking at this surface we are always aware of the surface itself, the surface does not disappear the way that a movie or tv screen does. When an image is displayed on one of these surfaces we do not have the 'window-like' deep space illusion seen in painting and films.

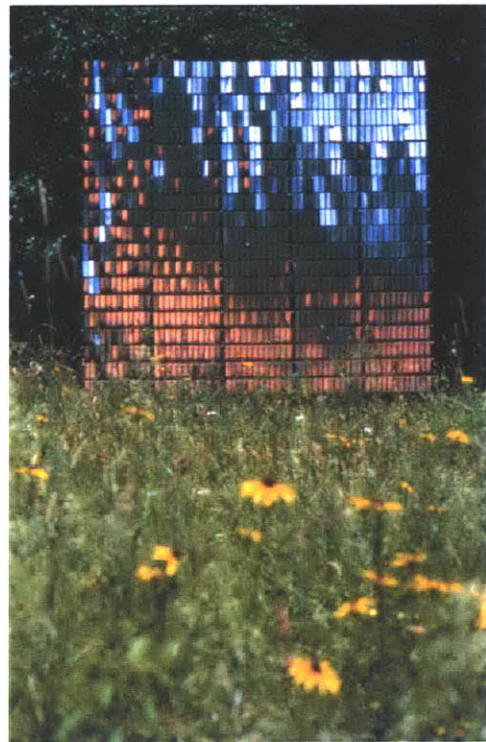


Fig w3: Tim Prentice, "Square Wind Frame".

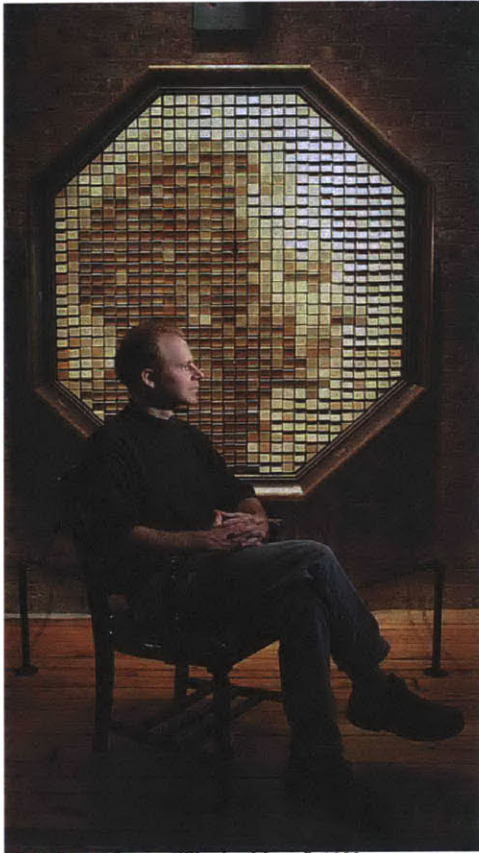


Fig 4: Daniel Rozen. "Wooden Mirror". 1999



Fig 5: Daniel Rozen. "Trash Mirror". 2002

Precedents

There are a number of recent projects that are precedents and inspiration for the research in this thesis.

First among these is the work of interaction designer and software engineer Daniel Rozen. His project 'Wooden Mirror' (Fig04) uses a computer, microcontrollers and servo motors attached to individual blocks of wood to create a wooden display device. An array of 144 blocks of wood rotate vertically with a light source above, as the blocks rotate they receive differing amounts of light and act as pixels on a screen. The rotation of the blocks is coordinated by a computer and a series of microcontrollers. What is most engaging about this work is the use of such a humble and seemingly non digital material such as wood. Daniel Rozen's went on to rebuild 'Wooden Mirror' out of different materials; eg. small pieces of trash found around the city for Trash Mirror (Fig05), studying how different the same mechanism and idea is when constructed out of a alternate material. 'Trash Mirror' is a bit of a letdown as it takes the sophistication of 'Wooden Mirror' and turns it into a one liner. One of the shortcomings of 'Wooden Mirror' is its presentation in a mirror frame (to contextualize its function) sells the concept short. Rather than seeing the surface as material with the potential to expand covering a wall and becoming environment, it remains contained and stays as an object within an its environment.

The 'Responsive Awning' by Micheal Fox actuated a series of sticks that projected from a surface, changing their x and y axis relative to the surface. (Fig 06) The movement of the projecting sticks was adjusted with x an y axis motors.

What is interesting about this project is that it was designed for a specific use. The project was meant to be both a display device and an awning over a storefront. The specifics of the program of an awning suggested the scale and guided design decisions in the project.

'Aegis Hyposurface' (Figs 07, 08) by Mark Goulthorpe and DECOi Architects uses a series of pistons pushing on a flexible metal surface to create display. Again a computer and series of microcontrollers is used to coordinate the output of the device, and again light from above is used to create image. The surface deformations created by the pistons bring this project out of the realm of surface and into the spatial. Where 'Wooden Mirror' is soft and human scale, 'Aegis Hyposurface' is cold in its precision and at a machine scale. This is neither positive nor negative as both projects evoke different emotions in similar levels of intensity. What is very successful in 'Aegis Hyposurface' is its evocation of an environment, when one approaches it, the viewer is clearly within its space and not vice versa.

One of the shortcomings of all of these projects is a lack of engagement of the tactile senses. All of these used physical deformations but remained as items to be seen. While there may be technical considerations as to why the viewer cannot touch these projects ('Wooden Mirror' may be fragile, 'Aegis Hyposurface' may be dangerous, 'Responsive Awning' was designed to be above people) this is still an area that needs to be considered in the design of a physical surface.

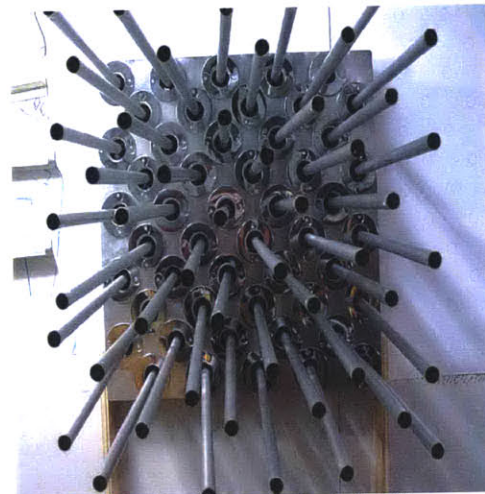


Fig 6: Michael A. Fox. "Responsive Awning". 1999



Fig 7: dECOI. "Aegis Hyposurface". 1999

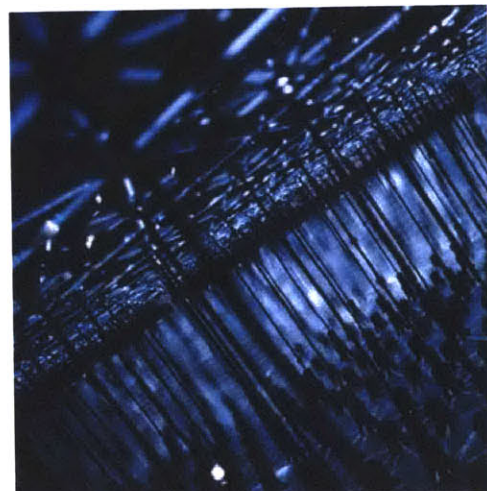


Fig 8: dECOI. "Aegis Hyposurface". 1999

Critiquing these projects individually misses the point. This paper views these works as the beginning of a field of research into electronically modulated materials. The research presented in this paper begins to flesh out areas of research for this field.

Inspiration

In 1851 Gottfreid Semper Published *The Four Elements of Architecture* in which he divided the practice of architecture in to the study of four basic elements: (1) the earth-work, (2) the hearth, (3) the framework/roof, and (4) the lightweight enclosing membrane. Of these four elements Semper placed the greatest emphasis of research and importance on the lightweight membrane, traditionally textile. This woven surface is seen as having a perceptual primacy as the horizontal surface in architecture, to better understand our perception and the possibilities of this surface requires the technical study of how this surface is constructed (Figs 09-11)

The technical innovations of the early twentieth century in building construction allowed architects to leverage Semper's ideas of a textile surface as enclosing membrane into modernisms ideas of "free-plan" and "free-façade". Accepting this lightweight woven membrane as the primary architectural element, this thesis looks to incorporate the transformative power of electricity and information into the craft of production of a wall surface. Craft oriented methods of productions are used to study materials from simulations technical and aesthetic viewpoints. To reconsider the relationship between material and electricity this paper revisits key of moments when the relationship between material and electricity was called into question.

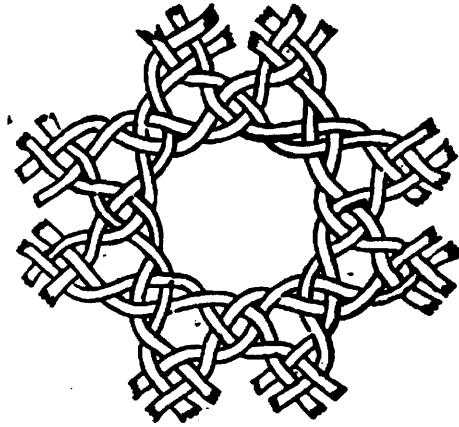


Fig 9: Gottfreid Semper, typical knot in traditional fabrics. 1863 (*Studies in Tectonic Culture*, 86)

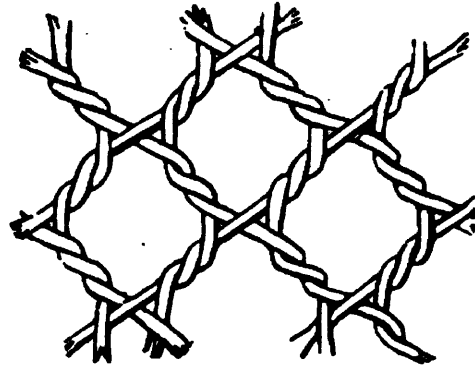


Fig 10: Gottfreid Semper, typical knot in traditional fabrics. 1863 (*Studies in Tectonic Culture*, 86)

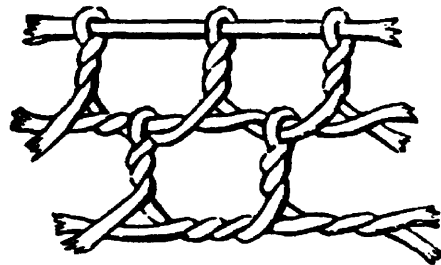


Fig 11: Gottfreid Semper, typical knot in traditional fabrics. 1863 (*Studies in Tectonic Culture*, 86)

Craft

The concept of craft, as an approach to this type of work, avoids the pitfalls of the artist or engineer in both design and production. In art or architecture the object is designed and manufactured as a singularity, a one of a kind. (there are exceptions to this idea but they are exceptions not the rule). Designed as to be the only one of its kind decisions become specific to the site, user, or whims of the designer, the manufacturing must be flexible enough to handle these whims, and thus often necessities hand production. The specificity and uniqueness of production is exemplified by the extravagant budgets of architect designed homes and the handmade nature of fine art. Engineering is the reverse side of this coin. In Engineering, design is used to as a problem solving exercise to optimize performance and/or production criteria. The advantage of engineering is the technical innovation that becomes the focus of attention over the aesthetic criteria of the design.

Craft and craftsmanship is based on an idea of a middle ground in both the design and production process. Within production the idea of craft is relatively clear.

As a verb “to craft” seemingly means to participate skillfully in some small scale process. This implies several things. First it affirms that the results of involved work still surpass the results of detached work. To craft is to care. To craft implies working at a personal scale – acting locally in reaction to anonymous globalized industrial production. (Abstracting Craft, 21)

The common language understanding of craftwork emphasizes the scale and the importance of the a human touch in production as a contrast to 20th century assembly line

production. In the past few centuries we have seen many craft traditions move by the wayside as modern production process create products once made by craftsman.

Where crafts have continued to flourish is where they have found a market that appreciates the type of design that fits this scale of production. Examples of this scale of production are presented in *Structure and Surface* an examination of contemporary Japanese textile design by Cara McCarty and Matilda McQuaid. The willingness to use both the most recent developments of cnc technology and ancient handcrafting techniques on the same project shows a willingness to use think freely about the use of technology in the process of production. In Reiko Sudo's 'Feather Flurries' (Fig 12) an automated weaving machine is stopped periodically to insert a feather by hand within the weave of the fabric.

These objects both exploit the medium of textiles and are in a medium of their own. They are handed off to any number of designers who use textiles as a medium in their own work. For example Makiko Minagawa (Fig 13) developed a run of textiles for a collection of Issey Miyake. These mediums are not the blank canvasses, rather these mediums that have the specificity and limitations.

For a medium to be engaging, it must be dense. This means that it must surround us in possibilities. Such immersion is more than sensory, for it also serves the imagination with opportunities to coax the medium to create a sense of continuum of possibilities. (Abstracting Craft, 190)



Fig 12: Reiko Sudo. "Feather Flurries" 1993. Silk organdy and Feathers, double weave. (Structure and Surface, 97)



Fig 13: Issey Miyake. "Prism Series: Coat (detail)." 1997. Wool, polyester chiffon, and batting, hand applied and needle-punched. (Structure and Surface, 93)

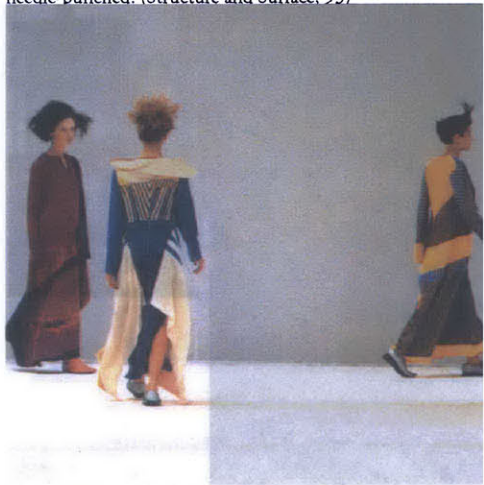


Fig 14: Issey Miyake. Runway Photograph of Prism Series. 1997. (Structure and Surface, 92)

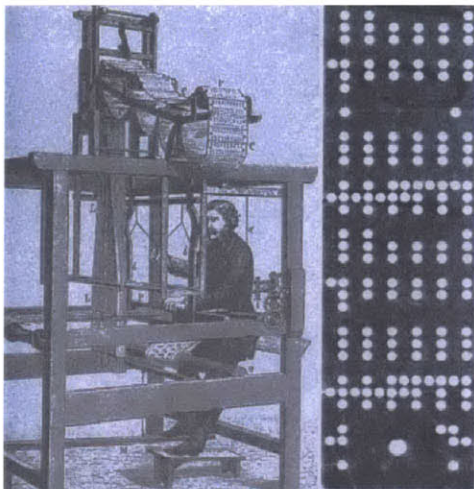


Fig 15: Jacquard Loom and Jacquard Loom Card. Invented about 1800. (A Computer Perspective, 92)

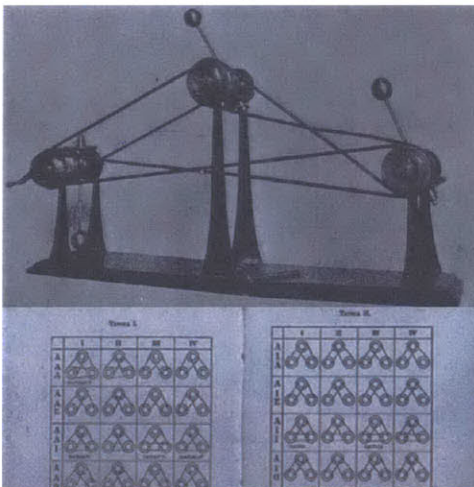


Fig 16: Pastore. Logical Automata and Logica Formale. 1890. (A Computer Perspective, 33)

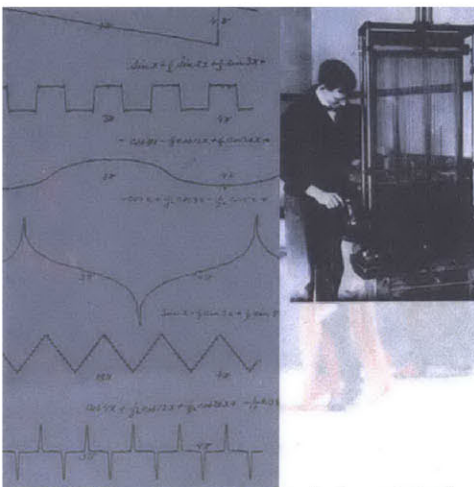


Fig 17: Michelson-Stratton. Harmonic Analyzer. 1890. (A Computer Perspective, 41)

Pre-History

A series of images and ideas from the history of computation suggest new ways of thinking about material, electricity and the viewer. Many of these are seen as dead ends in the line of computer progress, but if we try and understand what was the motivation in their creation it suggests alternative methods of thinking about computation and materiality.

As mentioned, the Jacquard loom (Fig 15), invented around 1800, was an key moment in the development of computation. Using a series of punch cards to control the movement of the battens the punch cards function as data storage. Changing the holes in the punch cards changes the results of the woven fabric. There is a direct correlation between the physical object and the “virtual” information stored on the punch cards. Most of the development of computation since 1800 has been in ways to manipulate the holes in the punch cards.

Figure 16 shows a device invented by an Italian professor of philosophy in 1903 to solve logical problems. The problem was encoded into the orientation of the belts, wheels and weights of the machine. Once the syllogism was encoded, the user would crank a wheel on the machine; if the syllogism was valid the wheels would spin. There were a total of 256 valid belt configurations. Physical form is used as a method of computation. There are other examples of physical computers, what is engaging about this image is that physical form is used to test abstract ideas. The physical form of the machine is developed as logic circuit not unlike the logic circuits of modern computers. Figure 17 is a beau-

tiful example of a physical computer. A harmonic analyzer able to perform Fourier analysis, breaking a complex irregular waveform into its component elements of simple curves.

Computers use a Boolean logic of true or false, typically represented in logic circuits by +5 and 0 volts. While a large part of computation is the development of operational circuits; storage data storage was major area of research that developed in conjunction with other computer advances. Early storage systems often had very visible tangible elements to hold temporary electrical states; these systems used various strategies to hold information. In the case of the Jacquard loom both the punch cards and the weaving itself are the data, although the weaving was not designed to automate the machine. Figure 18 shows a series of resonating tubes that were used to store information, information was stored as divisions of the frequency of resonation of the space. The tubes were used as temporary storage during calculations, over time the waves would disappear and the information would be lost. Figure 19 shows a similar system using cathode ray tubes. In these projects the properties of the physical form (resonance) is exploited as part of the electro-logical system. While the projects presented in this thesis do not attempt the engineering feats seen here, it is an attention to how physical properties in relation to electrical systems that is so inspiring.

Marshal McLuhan was able to see “electricity as an extension of the human nervous system” in something as mundane as a light bulb (Fig 20). What is unique about his vision is that it is not the application but the very medium itself has the transformative power. (His ideas can be further explored in his book ‘Understanding Media’).



Fig 18: Maurice V. Wilkes. "EDSAC" 1940. (A Computer Perspective, 155)



Fig 19: James Pomerene. Williams tubes from the Institute for Advanced Study computer. 1940. (A Computer Perspective, 157)

electric circuitry,

**an extension of
the
central
nervous
system**

41

Media, by altering the environment, evoke in us unique ratios of sense perceptions. The extension of any one sense alters the way we think and act—the way we perceive the world.

When
these
ratios
change,

men change.

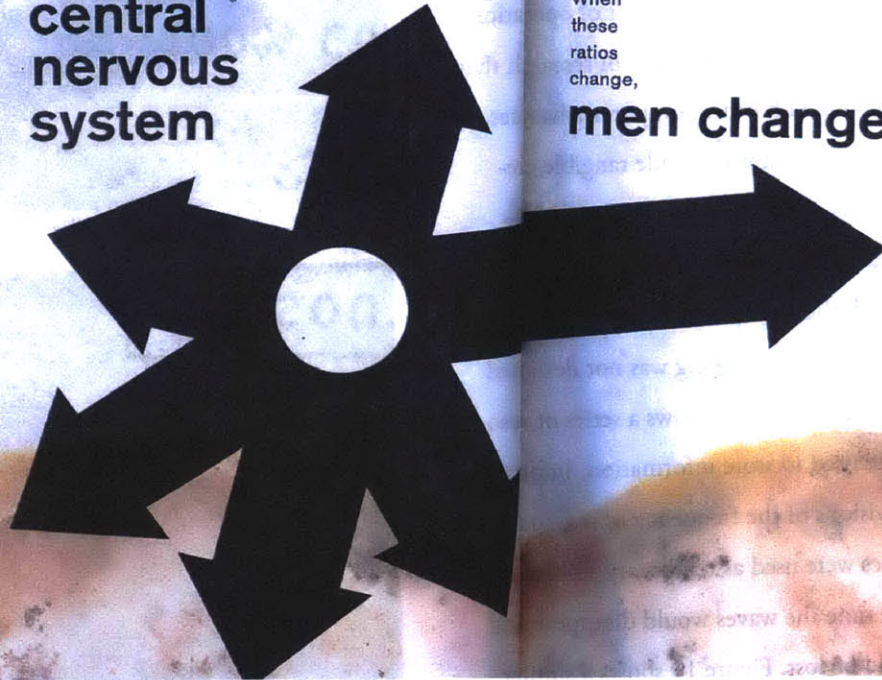


Fig 20: Marshall McLuhan. Electric circuitry, an extension of the central nervous system. (*The Medium is the Message*, 40-41)

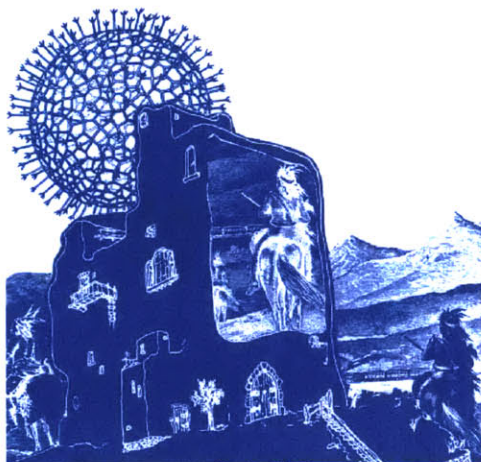


Fig 21: Illustration. 1971. (*Radical Software*, 12)

Ignoring McLuhan and sticking to our preconceived notions about electricity and its relationship to surface, space, and our bodies, allows us to focus on the information this electricity presents. Marshall McLuhan was writing this in the 50's, many of the ways in which electrical information is presented were already under development and yet he felt it was necessary to talk about the essential nature of electricity, of the light bulb itself. By allowing electricity to manipulate the physical world around us we are able to program not just the information we receive through electricity but rather our phenomenological experiences of this world.

McLuhan's thoughts were especially influential on people working in computation in the 60s. Ideas of cybernetics and ecological approaches to computation lead to striking results in the work published in the magazine 'Radical Software' (Figs 21- 25). The term software is misleading as most of the magazine was about cable television, video recording, and how technology creates new types of feedback loops. The illustrations of this magazine suggest electronic feedback loops changing our relationship with nature, ourselves and the city. While cable tv failed to deliver as medium capable of creating such perceptual and social changes, current technologies underdevelopment begin to approach ideas seen in these illustrations.

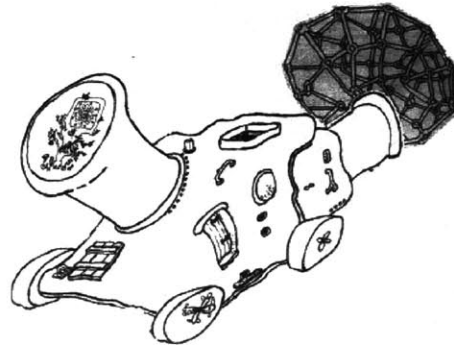


Fig 22: Illustration. 1971. (Radical Software, 14)



Fig 23: Illustration. 1971. (Radical Software, 17)

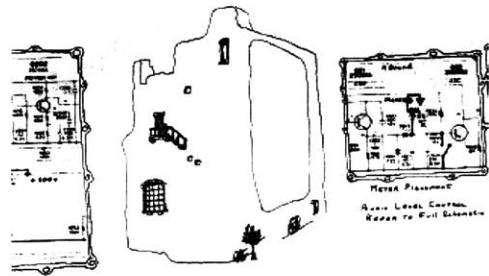
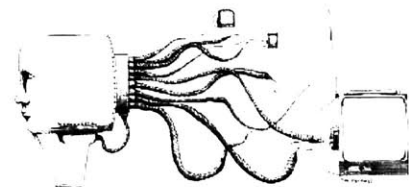


Fig 24: Illustration. 1971. (Radical Software, 21)



ACID PROGRAMMING

Fig 25: Illustration. 1971. (Radical Software, 25)

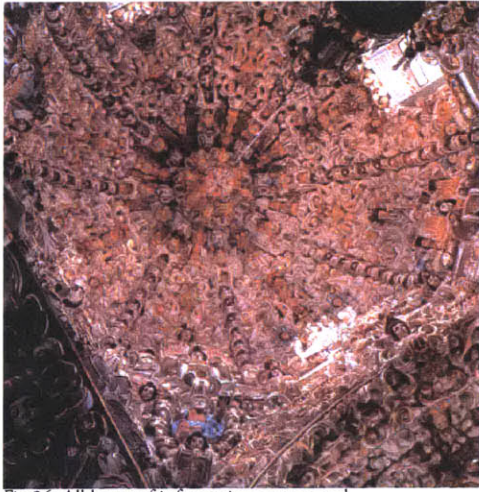


Fig 26: All layers of information compressed.

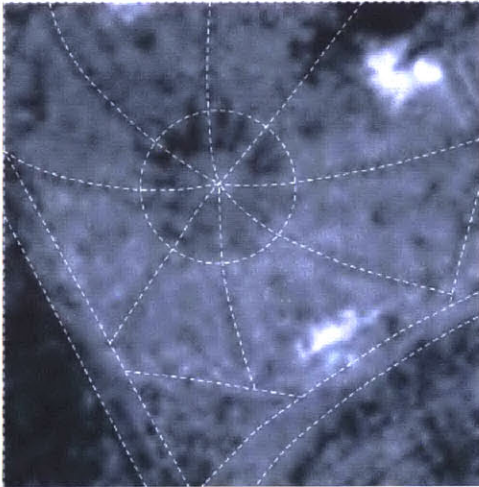


Fig 26: Formal/spatial layer of information.

Interface and Ornament

Researchers who have attempted to expand computer interfaces to the architectural scale carry many of the shortcomings of contemporary computer interfaces with them. Presenting moving image and information in a space is not at all like presenting information on a screen or desktop. The decorative arts have been dealing with the intersection of space and information for years. While traditionally integrated within the design of a building, modernism has seen their role move the wayside (postmodernism aside). The goal of incorporating digital interfaces into architectural space suggests new roles for the knowledge base of the decorative arts.

Projects that attempt to create a fully immersive environment with multiple projections covering every surface seldom move out of the realm of illusionist entertainment. A current example of this research is the IBM everywhere display . Their largest shortcoming is phenomenological, there is a strong disconnect between the information and the surface; an awareness of the phenomenon of projection. In the work presented in this thesis there is a direct integration of information and material. The information is part of the material properties; the interface is conceived as a material not as object. The tight linking of the information and the physical properties of the material cannot be understated.

Mark Weisner in his work and writing about ubiquitous computing created new ways of thinking about computers in our daily lives (Weisner, 4). By creating small computers that are commonplace throughout a space the user no

longer 'sees' the computer , just simply uses it. Similar ideas have been suggested by Hiroshi Ishii in his work with the Tangible Media Group. Ishii has suggested an 'Ambient Media'; interfaces that are designed to not be attended directly but rather peripherally. (Ishii, 3) The studies presented in this thesis fit within this line of thinking about computation but focus on the visual design of output surfaces.

The balance between foreground and background attention is one of the key issues dealt with in the Decorative Arts. E.H. Gombrich in his work on the decorative arts "The Sense of Order" explains difference in perception between the decorative arts and the fine arts. Gombrich refers to the decorative arts as 'the Unregarded art'

wallpaper, the pattern on the curtains, the scrolls on the picture.. rarely invite conscious scrutiny. True also may fail to notice a picture in a room or see it merely as a patch on the wall, but we know all the time that it is meant to be focused and contemplated. Painting, like speaking demands attention whether or not it received it. (The Sense of Order. 116)

The decorative artist uses a variety of techniques to create ambiguous moments between foreground and background attention. It is worth emphasizing the technique of balance between perspectival space and flat surface, as it creates a conceptual shift in thinking about an interface of information. Decorative surfaces present information that responds to the design logic of the form and space of the surface, information that creates its own internal logic of texture, and information that becomes representational or 'virtual' *'the oscillating interplay between representation, fiction and pure form which establishes yet another dimension for the decorator in his construction of hierarchies'* (The Sense of Order. 116)

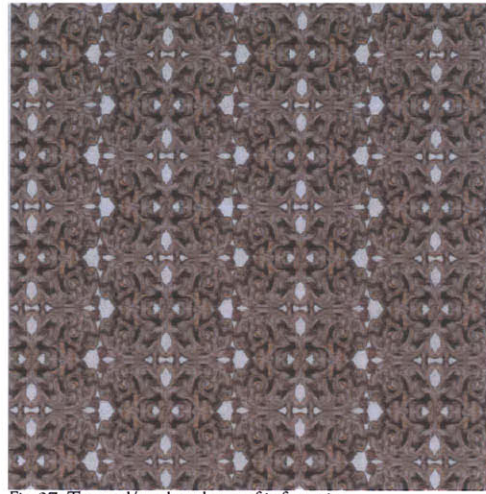


Fig 27: Textural/yardage layer of information.



Fig 28: Pixel/unit layer of information.



Fig 28: Facciata. Nuestra Señora del Buen Suceso (1755-1797) Santiago Tlanguistenco, Mexico. (Barocco Latino Americano, 85)



Fig 29: S. Prisca Taxco, Mexico. (Barocco Latino Americano, 211)

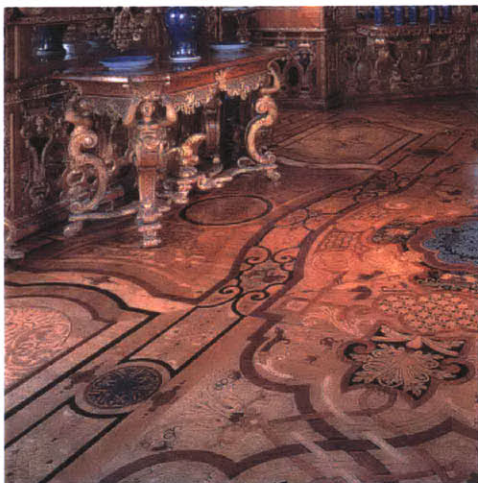


Fig 30: Ferdinand Pfitzer. Inlaid Floor. 1714-1719. Schloss Weissenstein, Pommersfelden, Germany. (Form and Decoration, 132)

Form and Decoration

In this example of a Latin American baroque church the decoration engulfs the structural elements of the building (Fig 28). Ornamentation dissolves the structure into delicate twisting lines while elevating the structural elements position in the visual composition of the façade; the plane exterior envelope recedes into the background. This strategic use of decoration at the moments of structural connection is reminiscent of classical ideals. The limited use of the expensive decoration is used to cover potential problems at joining of materials that occurs at moments of structural connection.

In Figure 29 the decoration has overwhelmed the form and structure of the wall. The complexity, intricacy and multiplicity of individual elements blur into surface from afar. The religious subject of the decoration is tied directly to the visual effect of overwhelming the viewer, creating a sense of awe and religious ecstasy.

In Figure 30 the ornamentation of the walls and furniture has moved to the floor plane in this interior. The imagery of the inlay floor borders on illusion. While there are strong traditions of *Trope L'oeil* decorative paintings as interior design elements it is still surprising to see this on the floor surface, perhaps because of its direct connection the body, our eyes seek to verify it as flat surface.

The Rietveld-Schroder house uses a limited palette of primary colors to emphasize modernist, planar elements of the architecture (Fig 31). The tight linking of the color to the formal composition reveals the buildings non modern reliance on decoration. The color composition is used to link

various materials, the building and the furniture into one single composition. One of the strengths of surface decoration is its ability to unite disparate forms and materials into a single spatial composition. In the Rietveld-Schroder house we see a tight linkage between decoration and form elsewhere this linkage is loose or even contradictory.

The unusual placement of baroque ornamentation on a cement truck allows a multitude of readings, and critiques, of political power and colonialism (Fig 32). The visual pleasure of the work arises from the contrast between the ornate decorative elements, on the banal, utilitarian truck. How our perception of the truck is changed by the artist treatment is a testament to the power of ornament.

Sol Lewitt's instruction drawings are conceived independent of a specific wall and then following various rules adapt to become specific to their site (Fig 33). It is worth considering the cultural norm of viewing these drawings as 'fine art' rather than 'decoration'. Clearly a modern view of the subject, it brings into question if there is a modern equivalent of the traditional artisans for the masterworks of the decorative arts seen in architecture of the past.

In Haeckel's rendering of the *Ostraciontes* (Fig 34) the surface of the fish is covered with an hexagonal pattern down to the shape of its mouth. The drawing shows four distinct varieties with this species of fish and how the tiling pattern has adapted to fit each. On one hand this shows in nature a geometric surfacing system that adapts to the form of the fish, I would hesitate to jump to this conclusion. Haeckel's relationship to ornamentation is more complex than just that of a scientist working objectively cataloguing nature. It



Fig 31: Hans Schroder. Interior view of Rietveld-Schroder House. 1924. (Ornament and Abstraction, 134)



Fig 32: Wim Delvoye. "Cement Truck" 1990-1999. Carved teak wood. (Fresh Cream, 224)

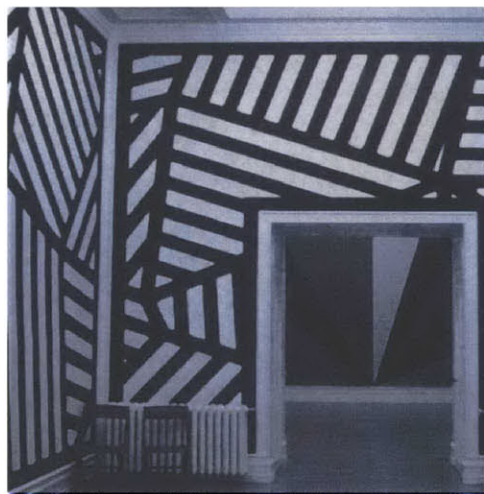


Fig 33: Sol Lewitt. Wall Drawings. Exhibition, Kunsthalle Bern, 1989. (Ornament and Abstraction, 149)



Fig 34: Ernst Haeckel. Ostraciontes. Koffersfische. (Art Forms in Nature, 42)



Fig 35: Ernst Haeckel. Nudibranchia. Nacktkiemer-Schnecken. (Art Forms in Nature, 43)



Fig 36: The nest of the bower bird. Introduction Plate II; (The Sense of Order)

has been documented that Haeckel images emphasized the order and ornamental and symmetries in nature at the expense of accuracy to push forward his agenda of 'Art Forms in Nature'. (Haeckel, 13) While Haeckel sought out forms in nature that reflected his own views on art and ornamentation, his work was influencing designers and decorative artists.

What is so striking about these renderings of invertebrate animals (Fig 35) is how they appear as formless clumps of ornamentation. As if without structure decorative elements develop their own forms of self organization.

The bower bird's claim to fame is his 'stage', built to attract females to mate with. The bird builds a wall, or maypole, of sticks as a canvas that he then proceeds to decorate with flowers, shells, and other objects. Birds of the same species will have different 'tastes' in décor, some may have an affinity for blue or green objects, others prefer shells. E.H. Gombrich in his book "The Sense of Order" sees this bird as attempting to create a space that is distinct in ornamentation from the disorder of the forest. *'it creates a little island of order, which corresponds in the visual realm to the patterned call with which the bird accompanies this display'* (The Sense of Order, 6)

Object and Surface

The positioning of this artwork (Fig 37) around a corner, rather than center, of a wall gives the artwork a spatial region that is independent of the geometry of the wall. This is to say the dots in the artwork suggest a spherical cluster that only becomes visible at its intersection with the wall. Another reading of the same situation suggest the dots as a part of the surface of the wall wrapping around the corner. Irregardless of reading it is important to note is how the artwork and the wall surface transform each other.

A field of thumbtacks covers both the wall and the artist in 'Tattoo #2' (Fig 38). The disturbing nature of thumbtacks placed into his skin aside, this photograph is not unlike a scene from a children's cartoon where character is painted with a wall surface, only to move away from the wall leaving their outline behind. The thumbtacks form the surface of a matrix that does not differentiate between the wall and a person standing in front of that wall. There is a visual fluxuation between perception of the person as part of continuous surface of thumbtacks and an object separate from the wall.

"One day I was looking at the red flower patterns of the tablecloth on a table, and when I looked up I saw the same pattern covering the ceiling, the windows and the walls, and finally all over the room, my body and the universe. I felt as if I had begun to self-obliterate, to revolve in the infinity of endless time and the absoluteness of space, and be reduced to nothingness.
---Yayoi Kusama

As patterns move beyond a single surface and begin to unite all elements in a room into a single environment it can have

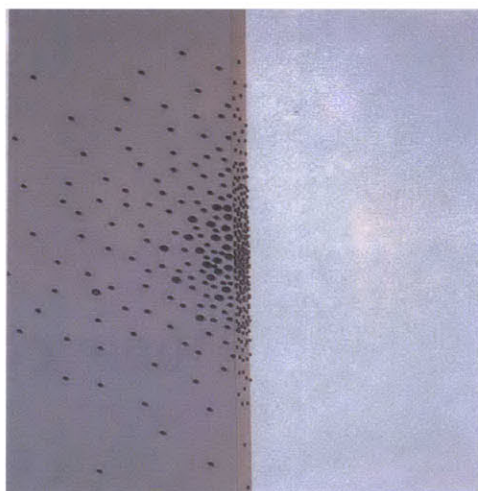


Fig 37: Lucky DeBellevue. Untitled. 1999. Self-sticking dots. (Fresh Cream, 217)

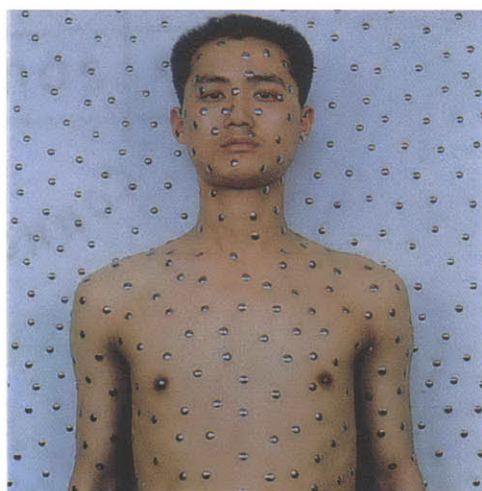


Fig 38: Qiu Zhijie. "Tattoo 2" 1994. Color photograph. (Fresh Cream., 485)

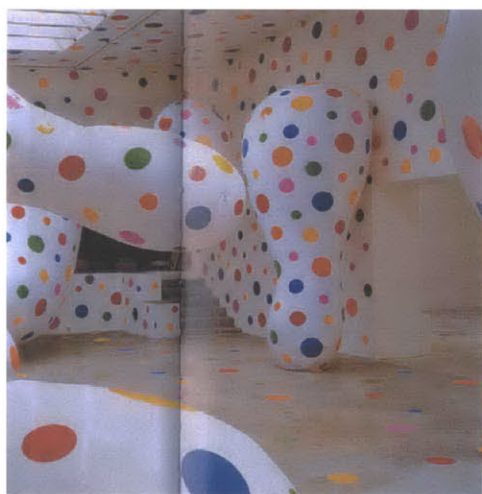


Fig 39: Yayoi Kusama. "Dots Obsession" 2000. New Century Le Consortium, Dijon.



Fig 40: Bahia Brasile Convento di S. Francisco. Chiesa 1708-1713. Particolare dell'interno. (Barocco Latino Americano, 205)

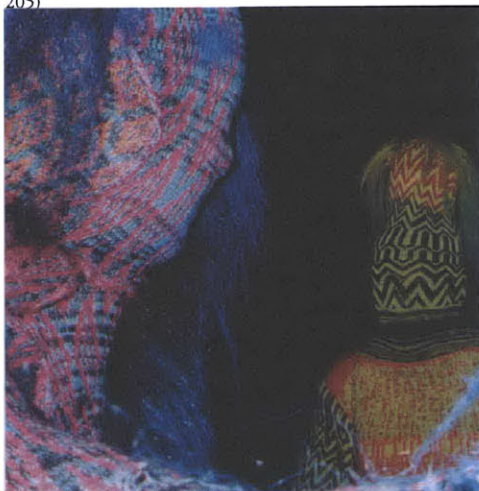


Fig 41: Force-Field. On Website.



Fig 42: Adriana Varejao. "Tea and Tiles" 1997. Oil on wood, porcelain, (Fresh Cream, 627)

dramatic disorienting effect. This quote and image by Yayoi Kusama (Fig 39) reflect the overwhelming visceral power of pattern, its ability to 'obliterate' not only distinctions between surface and object but also object and viewer.

While Yayoi Kazuma's dotted surfaces lean towards a 60's acid trip this Brazilian Baroque church (Fig 40) is using the same bag of tricks for ecclesiastical goals. Notice how the pulpit in the image has little compositional hierarchy over the decorative units of the surface, appearing more as a cluster of decoration than a programmatic element.

A photo of a concert of the art/music collective Force-Field portrays its members engulfed in vibrant cocoons of their own design (Fig 41). The vivid continuous patterns match the wild, 'effect-heavy' psychedelic music they perform. Their music and their costumes are all texture and surface; form and melody are an afterthought at best. Sensory overload moves to the forefront as the subject of the art/music.

The term modulation in the title of this thesis is a reference to the audio effect units such as a phaser or delay. Audio effects are added as an additional layer to the melody, or form, of the music that act to destabilize the melody. At times these textural effects can become subject of the music, as is the case with a band such as Force-Field.

In 'Tea and Tiles' (Fig 42) the surface of the tiles sits off-center on its frame seen through/on-top of, chairs and cups. This surface of tiles is primary over any physical formal elements in this work. The surface of the tiles presents images in 'delftware' scattered as jigsaw pieces. But the center of the tiles is an ocean, the sea, In this surface of the sea, captured in the blue and white of these tiles, imagery of old

world and new world are mixed.

In Gego's 'Reticulea' (Fig 43) a pattern as an organizational strategy asserts itself into space. This is different than structure (structure has connotation of hierarchy, of post and beams) this is pattern in space, all points and lines. All surfaces and space of the room are united in composition and sent into motion through the disorienting effects of pattern.

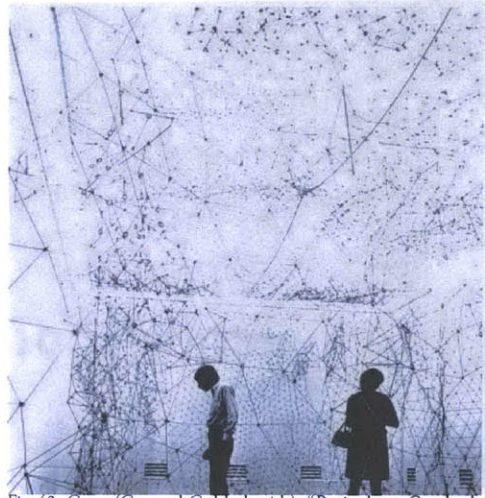


Fig 43: Gego (Gertrud Goldschmidt). "Reticulea Cuadrada (Square Reticularia)" 1971-1972. Stainless steel wire, small tubes, metal rings. (Forcefields, 116)

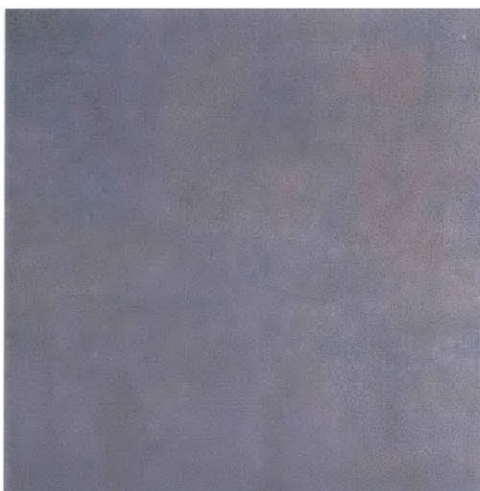


Fig 44: Yayoi Kusama. "No. White A.Z." 1958-1959. Oil on canvas. (Love Forever, 88)



Fig 45: Eva Hesse. "Untitled" 1967. Sculpt-metal and steel washers on wood. (Eva Hesse, 203)



Fig 46: Sergio Camargo. "NO.289A" 1970. (Forcefields, 112)

Texture and Discrete Objects

At first glance the Yayoi Kusama's painting 'NoWhiteAZ' (Fig 44) appears as little more than a textured white canvas. Closer inspection reveals a dense network of white and off- white lines filling the surface. The space between the lines resembles cells under a microscope, thousands of near identical elements that adding up to more than their sum. It is the visual conflict between perceiving the surface as either individual elements or texture that is the thrust of the work.

In this work by Eve Hesse (Fig 45) the individual elements are larger compared to Kusuma's 'NoWhiteAZ', but still read as texture because of their identical form. The work consists of a series of metal washers arranged in a grid on plane of wood. The art-historical critique of Eve Hesse's work as a feminine reaction to the masculine minimalist art, suggests a middle ground between hand and machine production. Although the steel washers were machine made, the artist allows slight shifts while aligning them on the surface of the wood. Changes in texture occur as changes in the surface finish of the washers. The identical size and repetitive pattern of the washers prevents visual hierarchy, leaving the work as a textured surface.

While the individual elements in 'No.289A' (Fig 46) near the forefront of perception the strength of the texture is clear as tactile feature. Without being able to touch this surface I find myself daydreaming about it would feel made out of various materials. Pattern crates texture and in turn how a surface feels, even when this texture remains visual it is understood through a internalized tactile memory.

These two works of Japanese textile design have similar structural elements (Figs 46, 47); both are a continuous surface of one material with short linear elements of another material running in parallel. The importance of scale in texture is evident in comparisons between these two works. The scale of the work is dependant upon the smallest elements and their relation to the overall composition. This fact is often exploited in architectural facades and ornamentation where large elements become texture because of viewing distance. But in a textile work the tactile experience sets the scale to the human body. The paper elements in the Reiko Sudo piece are too small and varied to be perceived as anything but texture, the similar wool elements in the Hideko Takahashi piece are on the other hand visually and tactilely distinguishable.

The Yuh Okano fabric (Fig 48) differs from these pieces in the lack of a backing surface. The bundled, “all-ornament”, nature of the fabric shares an affinity with Haeckel’s Plate 43 of invertebrates. Without an underlying structure these objects appear formless; we are unable to understand the form in relation our internal vocabulary of forms. These forms are beyond the baroque, while the baroque is the classical form distorted so that the distorted and the original co-exist this moves beyond in the grotesque, and the formless.

The photo mosaics of former MIT Media Lab student Robert Silver use photographs as pixels of a larger image, utilizing color blending techniques not unlike offset printing, pointillist or post impressionist paintings. Cognitive scientist Magret Livinstone in her book ‘Vision and Art The Biology of Seeing’ explains these phenomenon as a



Fig 46: Reiko Sudo. “Patched Paper” 1997. Polyester and mino washi paper, Jacquard weave..(Structure and Surface, 87)



Fig 47: Hideko Takahashi. “Stick” 1996. Wool and tulle, Jacquard double weave, felted, rolled and dyed. (Structure and Surface, 70)



Fig 48: Yuh Okano. “Epidermis (Ocean)” 1994. Polyester, shibori dyed and heat set. (Structure and Surface, 72)

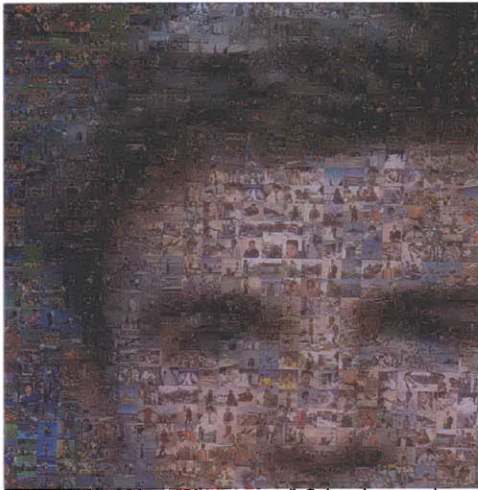


Fig 49: Robert Silver. "Photo mosaic" Color photography.
(Vision and Art the Biology of Seeing, 186)



Fig 50: Interior of the Church of Tonantzintla. 18th Century.
(Nature of Ornament, 157)



Fig 51: Gateway Temple of Srirangam, India. 17th Century.
Black and White Plate #5; (The Sense of Order)

mixture of two effects in the visual system. The first effect is referred to as color-blending and is the basis of offset printing (the perception of a mix of neighboring colors when they are presented at a small enough scale). What makes a pointillist image seems so vibrant while offset printing is mundane, is the difference of the scale of the smallest units relative to our retinal image. There is a higher resolution in our central, then peripheral, acuity. *'the part of the image you see with the center of your gaze appears to be made up of dots, but the surround parts, seen by your peripheral vision, are perceived as a more homogenous surface'* (176). The switching back and forth between these two visual systems accounts for the vibrancy and movement on surfaces that manage to straddle between these two perceptions; i.e. surfaces such as a pointillist painting or photo mosaics.

The second visual effect is the difference in the level of resolution in the color and form systems of the brain. The brain uses high resolution to distill form from a retinal image and store a perception in short term memory. The brain then 'fills in' this image with the lower resolution color system. When the filling in does not match the reality of the image this creates an optical illusion of blurring color across an area that is perceived as a one form.

In an architectural setting the scale of the individual units of a texture are not static, but rather relative to viewers position in space. Figures 50 and 51 are examples of building using a multitude of scales to portray texture from a distance, and individual elements closer to the surface.

Hierarchy

In the early 20th century visual perception was understood through a structuralist ideology; a series of small building blocks called sensations added up to form our perception. Developed as a counterpoint to this Gestalt psychology suggested that the parts are greater than the whole, that we are able to fill in the blanks in an image using the Gestalt laws of perceptual organization. These six laws explain how we organize the information we receive in our retina into a perception of the world. When these relationships are ambiguous multiple perceptions of the same image arise.

There is vagueness to the Gestalt rules; their strength lies in explaining perception after the fact, rather than predicting. The six laws of Gestalt organization are: 1: *Pragnaz*. A German term translated as 'good figure, simplicity'. The law of good figure means that we seek the simplest explanation of a visually ambiguous image. 2: *Similarity*. Similarity refers to the perception of objects with similar properties as a group, such as grouping red from blue objects. 3: *Good Continuity*. This describes the perception that objects continue even when they are visually occluded by another. 4: *Proximity or Nearness*. Perceiving objects near one another in an image as a group. 5: *Connectedness*. The perception of objects touching each other as a group. 6: *Common Fate*. Common fate is most often used to explain the perceptual grouping of objects moving in a similar direction. 7: *Meaningfulness or Familiarity*. This is again rather vague, but this law refers to the use exceptions and understating of the world to organize perceptual ambiguous moments.

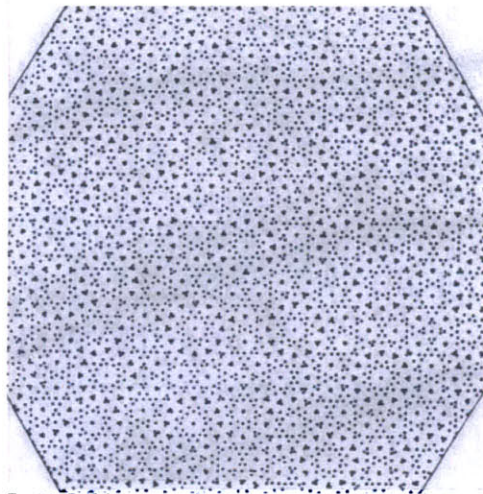
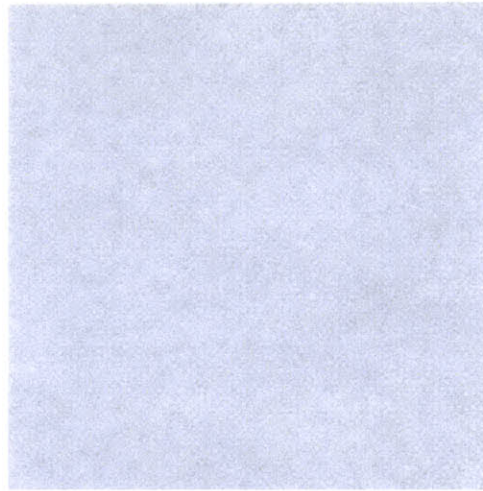


Fig 52: D. Marr. 1982. (Art Forms in Nature, 21)

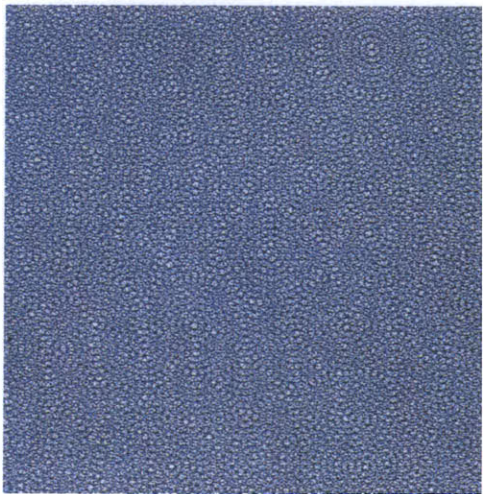


Fig 53: Francois Morellet. "22 Meshes" 1960. Page 103; Forcefields.



Fig 53: François Morellet. "4 Double Meshes, Thin Lines" 1958. (Forcefields., 101)



Fig 54: Henri Michaux. "Dessin de Reagreation" (Post-mescaline Drawing), 1966. (Forcefields, 25)

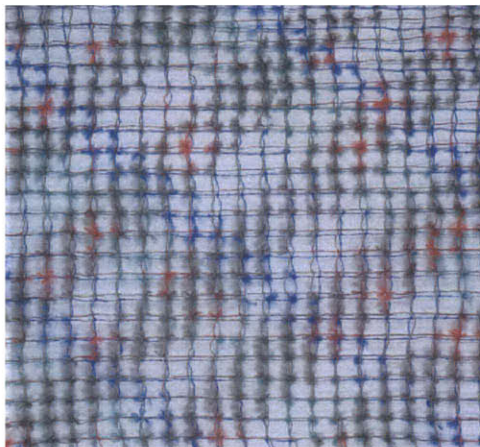


Fig 55: Joanne Segal Branford. "Plaid Net" 1976. Netting, linen. (The Art Fabric, 105)

The drawing of Arabesques in Figure 52 is taken from David Marr's book on Vision, when viewing this image one perceives a change of pattern on three second intervals. This change is understood by Marr to be the pulsation of our brain attempting to resolve the image into simple shapes. At each instant of this pulsation we are using Gestalt rules of organization to visually simplify the image into groups.

Curator Guy Brett in his critique of the work of Morellet (Figs 53, 54) sees the artist as using the perceptual pulsations experienced in viewing his work as the subject of the work *'in the series of works, form is dissolved into an energy field, one of great density and delicacy'* (ForceFeilds, 38).

Brett sees in the work of Morellet an affinity with the work of Michaux (Fig 54), known for his experimentation with Mescaline and its influence on his work. There is a strong and consistent relationship between pattern and altered states of consciousness.

The perceptual organization of 'Plaid Net' (Fig 55) plays on the same visual phenomenon of color-blending mentioned in the discussion on photo-mosaics. The form and structure of the work run as a orthogonal grid up and down the surface, while the color runs in diagonal lines across the surface. The color has a tendency to blend across the white space to perceptually form diagonal bands. The artist furthers the effect with her material selection, the fabric frays into the blank space of the grid physically mimicking the perceptual color-blur.

What is not portrayed in the image of 'Square Kinetic Object' (Fig 56) is how the small white strips are in motion, rotating randomly via motors behind the black

surface. While I have not seen this work nor have I been able to find a description of the motion of the motors I can imagine them slowly shifting and shimmering. As the white lines occasionally align, small groups and illusionary forms are created that attract the eyes attention, only to see them disperse.

In “Composition With Circles” (Fig 57) Bridget Riley exploits the spatial conditions of the gallery to enhance the perceptual impact of the work. A wall drawing, the work fills a 13’ x 35’ wall to the edge as if the drawing continues off the wall beyond the viewers vision. The size of the gallery does not allow the viewer to take the entire surface in at once. This leaves much of the image in the lower resolution peripheral visual field of the eye enhancing illusionary effects.

Yayoi Kusama’s use of colors with similar hue and luminosity, adds a layer of complexity to the visual pulsations of the piece. Cognitive Scientist Anne Triesman’s theory of Feature Integration can help explain what happens when we view this artwork . Triesman’s work begins with an examination of the ‘pop-out’ phenomeon of visual search. The term ‘pop-out’ refers to how a red object among a field of blue distractors will ‘pop-out’ form its background. When additional red objects are added of different shapes the ‘pop-out’ phenomenon no longer occurs. In her 1980 paper ‘A Feature-Integration Theory of Attention’ Treisman describes a series of feature maps that are used in early visual processing to pick features out of a selection set. These feature maps work in parallel across our visual field, when the object we are looking for is not the only object with its set of features we use attention to scan across our

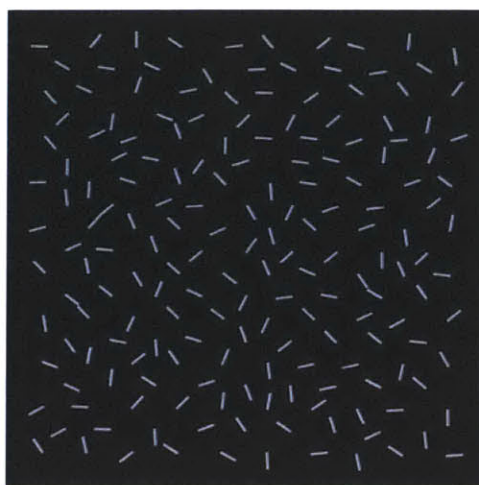


Fig 56: Gerhard von Graevenitz. “Square Kinetic Object: Black With Short White strips” 1965. (Kinetic Art, 79)

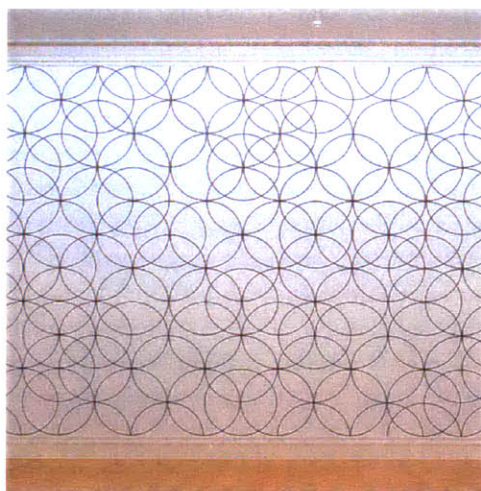


Fig 57: Bridget Riley. “Composition with Circles” 1998. Wall drawing. (Bridget Riley: Reconnaissance, 50)

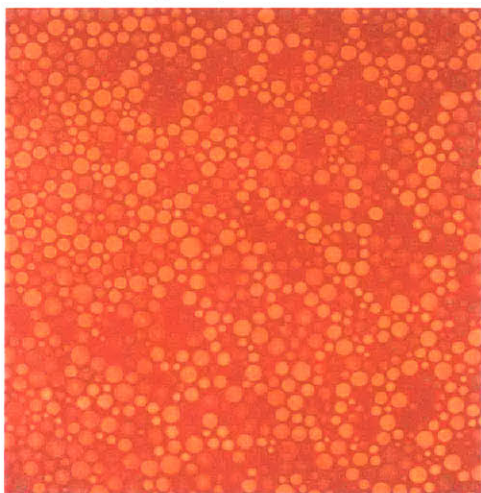


Fig 58: Yayoi Kusama. “Dots Obsession” Acrylic on canvas. Plate 12; Yayoi Kusuma: Now.

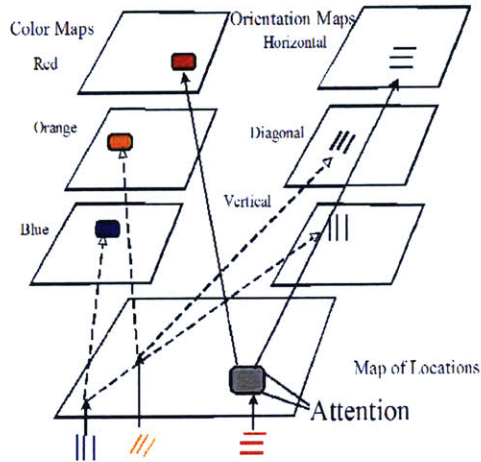


Fig 59: Anne Treisman. Diagram of Feature Perception. 1980 (Treisman, 05)

retinal image and conjoin the sets of feature maps into an object. Figure 59 describes this process through a diagram. What is so engaging about the work of Yayoi Kusama is that we are not able to conjoin features into objects because of the activation of identical feature maps by various objects within the image. At the same time the individual elements are too unique to be viewed as single visual object or texture.

The most successful of all these works of surface design are able to put strain on our mid-level visual processing. The term low-level processing refers to the functioning of our eyes, edge detection, image generation, and how they take information into our brain. While high-level processing deals with meaning and so called higher brain functions. Mid-level processing organizes the retinal image into perceptions of objects and depth. While these descriptions are less than perfect they function well as rough groupings. Additionally we say a work of art is successful because processing done in higher brain functions, in layman's terms this is to say that we 'think about' something. The subject matter of works of art and design that strain mid-level visual processing is often either related to either drug use or religious transcendence. As we expend more of our brain resources on mid-level processing, (processing that does not deal with semantics or meaning) our upper brain becomes free to wander, allowing moments of the transcendental.

Figure and Ground

An image that has an equal visual balance between black and white, without shades of grey, is a text-book example for figure ground reversal. Filling the frame, this example of growth patterns in nature, Figure 60) gives few clues as to what is figure or ground.

While the same techniques used in Figure 60 are seen in Figures 61 and 62 to create figure ground reversals, the images in Figures 61 and 62 use techniques of pattern design to manipulate the visual hierarchy of the image, this hierarchy in turn has an effect on the relationship between figure and ground. In Figure 61 when the quarter circles are rotated so that they form a full circle, the circle moves forward in the visual field as figure. In Figure 62 when matching color diamond shapes face each other creating a zig-zag line of opposite color, the diamonds appear as figure. In traditional surface and wallpaper design the artisan needs to consider the design of both the unit (the smallest repeatable part of the pattern) and the yardage (the overall appearance of the pattern).

There has been work in mathematics and computer science dealing with pattern organization and recognition, what that work lacks is the limitations of human scale that traditional craft production brings. That is to say while the scale of a pixel allows infinite possibility; the scale of the woodblock encourages thinking through the mediums limitations. With a woodblock pattern there are only so many possibilities of how the woodblock can be rotated and manipulated so the designer's attention turns from yardage to unit. In Figure 61 this manipulation can be seen



Fig 60: David Wade. Winding and Turning Forms. (Li: Dynamic Form in Nature, 7)

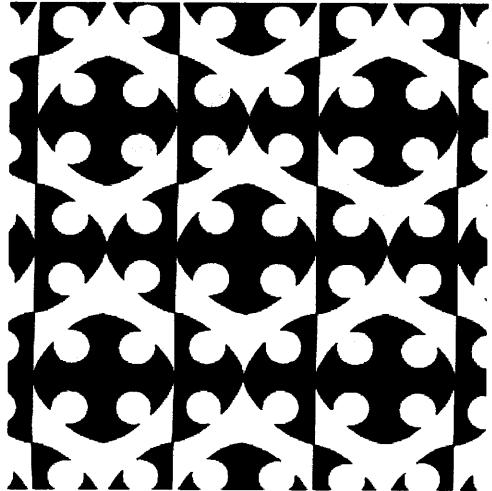


Fig 61: Norma Beale. Cut paper design. (Principles of Pattern, 69)

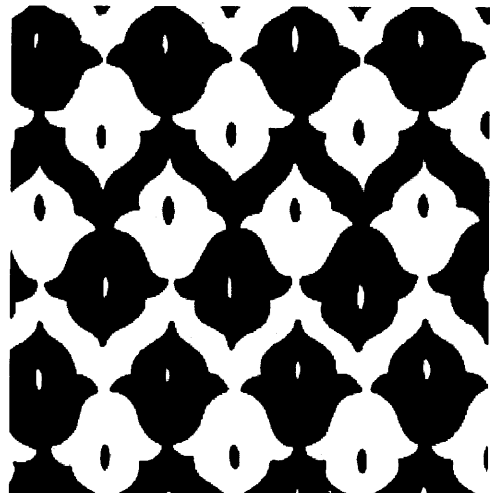


Fig 62: Tile, Mihrab of Mosque of EmMu'ayyad. Early 15th Century. Cairo, Egypt. (Symmetries of Culture, 198)



Fig 63: John Aldridge. Block printed wallpaper. 1939. (Twentieth Century Pattern Design, 74)

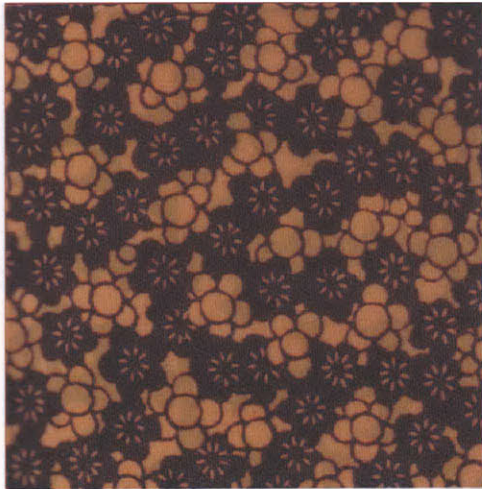


Fig 64: Motif of red and white plum blossoms. (Snow, Wave, Pine Traditional Patterns in Japanese Design, 128)



Fig 65: Coat (Attush). Late 19th Century. Ainu, Japan. Bast from elm trees, hand woven. (Ornament and Abstraction, 187)

in how the white circles establish their own rhythm on the composition. Figure 67 shows the 17 one-color two-dimensional patterns.

Figures 63 and 64 create figure ground relationships in color using detail and natural subject matter. At first glance Figure 63 is a simple diamond stacked pattern, with the blue diamonds moving forward as figure, against a ground of brown. The rendering of details in the pattern reveals a more complex story. The sinuous blue line running through the brown is rendered as a vine with foliage sprouting into the blue spaces, inverting the previous figure ground reading. The variations in foliage represented prevent the pattern from repeating between each block. Described as a “fine pattern”, Figure 64 uses detailed rendering to depict red and white plum blossoms. The layering of the images of the red and white blossoms avoids perceptual resolution.

The decoration on the coat in Figure 65 achieves an ambiguity of figure and ground, not through color reversals, but rather through its use of contour. In this way it has an affinity to the work of Bridget Riley. Line is used both, to denote a change in material or object, and to render the surface of an object. It is the interplay of figure and ground within the unit as well as between the units that creates a sense of complexity.

There is a very clear sense of layers in Figure 66. The field of multicolor circles extends behind the green cut-out contrary to the usual placement of detail in figure and ground (the tendency to see the area with more detail as figure).

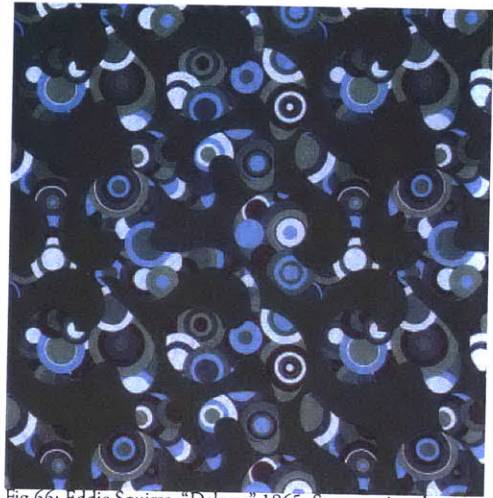


Fig 66: Eddie Squires. "Delores" 1965. Screen-printed cotton furnishing fabric. (Twentieth Century Pattern Design, 148)

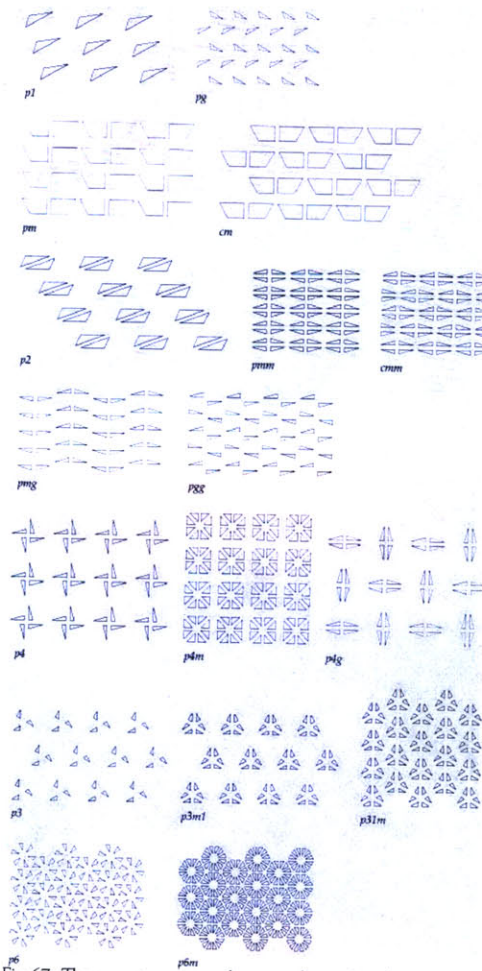


Fig 67: The seventeen one-color, two-dimensional patterns. (Symmetries of Culture, 61)

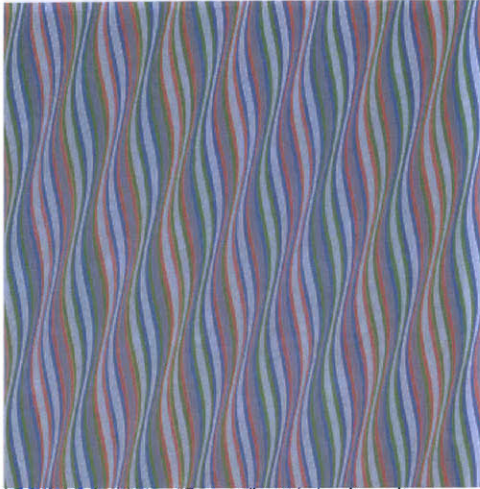


Fig 68: Bridget Riley. "Entice 2" 1974. Acrylic on linen.
(Bridget Riley: Reconnaissance, 95)

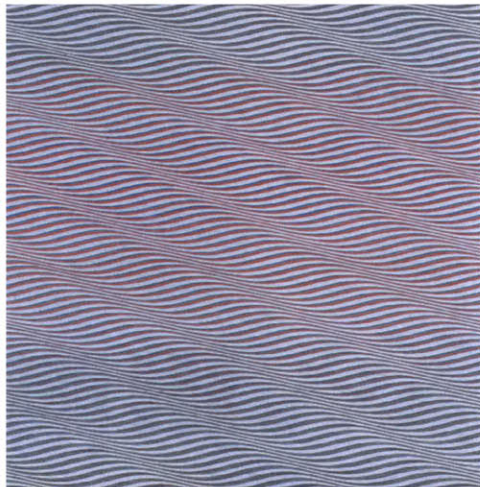


Fig 69: Bridget Riley. "Cateract 3" 1974. PVA on canvas.
(Bridget Riley: Reconnaissance, 85)

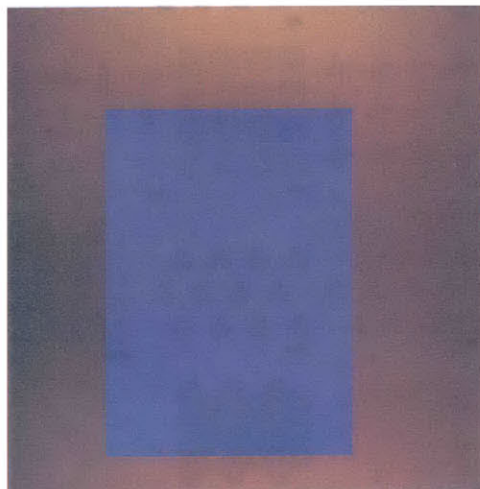


Fig 70: James Turrell "Skyspace I" 1975. PVA on canvas.
(James Turrell: The Other Horizon, 96)

Deep Space and Shallow Space

Most surface design appears to sit on the surface of an object as opposed to creating a perspectival window into its own virtual space, however there are designs that create a shallow space between these two, fluctuating between surface and depth.

Bridget Riley has taken the study of this experience to new levels of refinement, in these two works 'Entice 2' and 'Cateract 3' (Figs 68,69). In these paintings Riley is able to create a rhythmic fluttering between deep space and flat surface, tiring the eye down. Riley has said of her works that *'perception is the medium'*. So much of what is engaging about these paintings is in the brain of the viewer. The ability to manipulate perception with such limited means bears a similarity to the ideas of Marshal McLuhan; In that he did not just see modern technology and computation as an extension of the human nervous system rather he saw these ideas contained within such a simple medium as the light bulb. To leverage these ideas together to create surface that unite McLuhan's electrical extension of the human nervous system into an approach to surface that deals with perception is a goal of this thesis.

Rather than portraying deep space on a flat surface James Turrell's Piece "Skyspace I" (Fig 70) depicts a flat surface out of deep space. The artwork is as square hole cut in the ceiling of a room, when first entering the room it is perceived as a blue square painted on the ceiling. Perception of the blue square shifts to a realization that the blue square is not on the ceiling but rather the sky is visible through the ceiling. The sky appears alternately as a surface and as deep

as infinity, at times resting its surface on the roof or lowing its volume down and engulfing the viewer.

Chuck Close's portraits use scale and the detailing of the individual units to create a fluttering between depth and surface (Fig 71). Again the technique here is the same as the color blurring discussed by Margaret Livingstone.

The depth in these wallpaper designs, Figures 72 and 73, is shallow, rather than the deep space seen in a perspectival image. This shallow space is achieved with realism in the rendering of the naturalistic subject matter and sophisticated suggestions of layering.

The depth of space and relationship between representation and two dimensional surface shown in Figure 74 is exemplary of a tradition of Japanese prints. Moments of the design show an image of a village in perspectival rendering, while the river and fields of the image flatten out into a surface pattern. In many Japanese prints the blank space of the canvas, or paper, is neither the deep space seen in Western Post-Renaissance art, nor a flat two dimensional surface, this suggests possibilities of how surface design can move between foreground and background attention.

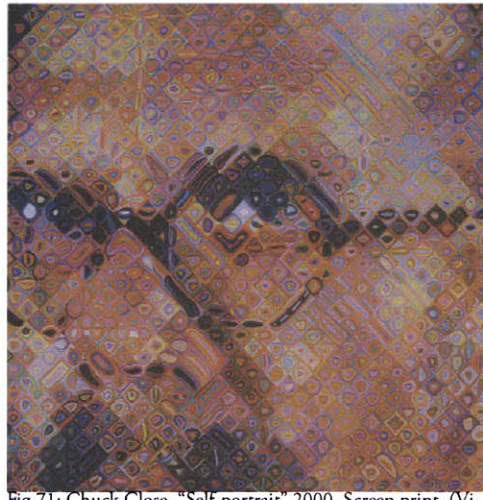


Fig 71: Chuck Close. "Self-portrait" 2000. Screen print. (Vision and Art: The Biology of Seeing, 185)



Fig 72: William Morris. "Jasmine" 1872. Block printed wallpaper. (Twentieth Century Pattern Design, 11)



Fig 73: John Henry Dearle. "Seaweed" 1896-1901. Block printed wallpaper. (Twentieth Century Pattern Design, 15)

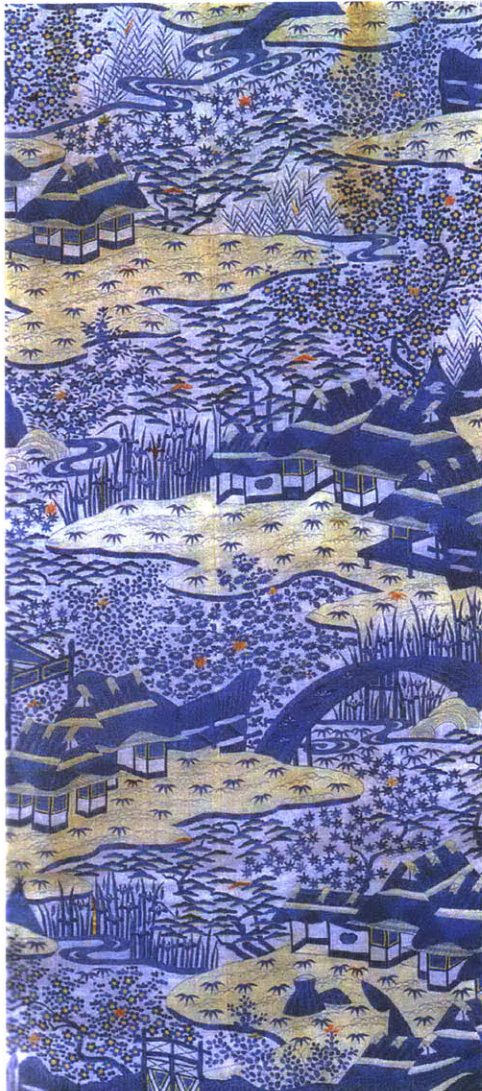


Fig 74: Bridge amid rabbit-ear irises, chrysanthemums, maple leaves, and pine trees. Detail of Katabira Summer Kimono. (Snow, Wave, Pine Traditional Patterns in Japanese Design, 107)

Level of Detail

The amount of detail in the individual units of Figures 75, 76, 77, and 78 is striking. These designs use the same yardage, a stacked diamond pattern, detailed to convey different information at various scales. Figure 75 keeps the overall structure of a stacked diamond pattern but reveals more information in the medium of flocking upon closer inspection. Figure 76 uses color changes to create a rhythm between a stacked diamond pattern and horizontal stripes. Figure 77 extends the stacked diamond into an ogilvie pattern that inverts itself with its interweaving details. Figure 78 creates a stacked diamond pattern that expresses physical texture.

The multiple readings of the information in a pattern depends on the scale of the pattern relative to the viewer. In these images three distinct readings of information are presented. From a far enough distance we blur the pattern into surface, and view the form that that surface describes, in this case a church. Closer to the surface we perceive the pattern as a surface texture independent of form, this is the scale of yardage. When close enough we are able to read information from the unit. The difference between a pattern unit and pixel/mosaic is that the individual units contain information. In a mosaic/ pixel metaphor the information is given by the parts adding up to more than the sum. In a pattern design the parts add up as well as stand alone.



Fig 75: Wallpaper. France. 1815-1825. Woodblock printed in distemper inks and flock. (More Than Meets the Eye, 96)



Fig 76: Woven Fabric. Spain. 16th Century. Silk. (More Than Meets the Eye, 74)



Fig 77: H. Crane Day. "L'Opera" Wallpaper design. (Principles of Pattern, 66)



Fig 78: Akihiro Kaneko. "# 1926 Brown Hair" 1995. Acetate, rayon and cupra, jacquard weave, cut and dyed. (Structure and Surface, 88)

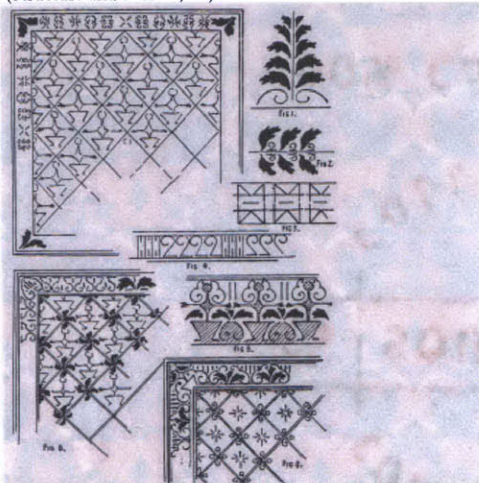


Fig 79: F.G. Jackson. Decorative Design. 1897. (The Sense of Order, 155)



Fig 80: Mise-en-Scene. Commemorative Toile. 1992. (New Material As New Media: the Fabric Workshop and Museum, 78)

John Ruskin defending the importance of the natural in ornamentation to his friend R.N. Wornum:

"My friend (Wornum) had been maintaining that the essence of ornament consisted of three things: - contrast, series, and symmetry. I replied (by letter)-'Here -(making a ragged blot with the back of my pen on the paper) - "you have contrast; but it isn't ornament: here: - 1,2,3,4,5,6, (writing the numerals) you have series ; but it isn't ornament: and here here (sketching a figure) you have symmetry but; but it isn't ornament"

The upper left hand corner of Figure 79 shows a drawing of a handkerchief that Wornum returned to Ruskin, while the rest of the image show how art historian F.G. Jackson further developed Ruskins limited vocabulary to create images such as flowerpots.

In Figure 80 each individual unit displays discrete information in a pattern that is read as homogenous from a distance. The individual units of the stacked diamond pattern each portray a different image from the history of American Slaves. In this artwork this technique is used to give a distant reading of traditional Victorian wallpaper juxtaposed against of a closer reading of a disturbing moment of American history, this same technique can bridge the gap between background and foreground attention.

The relationship between foreground and background readings of Figure 81 is the reverse of the previous example. in Ghada Amers's 'Untitled (rose/rose)' the pattern of needle-work roses that float foreground in the image mask the background image of a naked woman. The image's ambiguity allows a flip flop between reading of the image and space, as the roses float foreground in shallow space and the woman recedes into deep space.

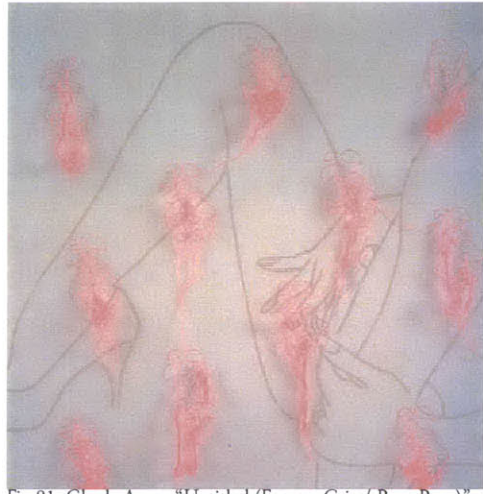


Fig 81: Ghada Amer. "Untitled (Femme Grise/ Rose Rose)" 1997. Acrylic and embroidery on canvas. (Fresh Cream, 72)

Proposals

Eight proposals of electronically modulated materials are presented in this section at various stages of investigation. The first six projects are presented as sectional/schematic drawings. The last two projects have been investigated to the level of working prototypes.

What makes each of these projects unique is the way that electricity changes the physical properties of the material. The disjunction between the digital representation and the physical instantiation of information is exploited to aesthetic ends. Often it is an issue of scale, the smallest unit of the digital information is larger than the smallest physical unit of the system. This allows a small digital change to have a large effect over the physical system. The shifting of scale creates an economy of computation and actuation that allows these systems the potential development at the architectonic scale.

The 'back-end' schematic of the electronics appears similar in most of these projects. As an output surface all of these projects use either a matrix or linear array of actuators. The control of these actuators uses a combination of microcontroller, multiplexer and relays.

The schematic is drawn to give enough information to an engineer to further develop the project for prototyping or production. A number of conventions are followed in the schematic design, the power and ground of the microcontrollers is not drawn, groups of wires or 'busses' are drawn as individual wires with a diagonal turn. Parts are not specified in the schematics awaiting further engineering.

Engineering research to further develop these projects will tackle issues of expandability. Which specific microcontroller used on a system is dependant on the number of units produced, and if the application uses the microcontroller as the 'brains' of the project or if the microcontroller acts a middleman between the surface and the computer. With the goal of an architectural building material in mind it is useful to develop the expandability of the system. The system itself becomes a building unit of material that needs to communicate with units of the system. Networking strategies of embedded devices is a growing field and to large to get into in this thesis.

As currently drawn in the schematic each individual pixel actuator is addressable, often with its own relay. The relays are necessary where the power of the actuator exceeds the power that a microcontroller can sink/source. An approach to solving this issue is through a model used in a number of displays (Fig 82); a matrix that sends rows and columns high or low so that then when they align power moves through the actuator or LED. This matrix acts as the relay for the higher power elements of the system. This model will not succeed in the systems that use static electricity because of the necessity to electrically isolate parts of the high voltage system to prevent electrical arcs.

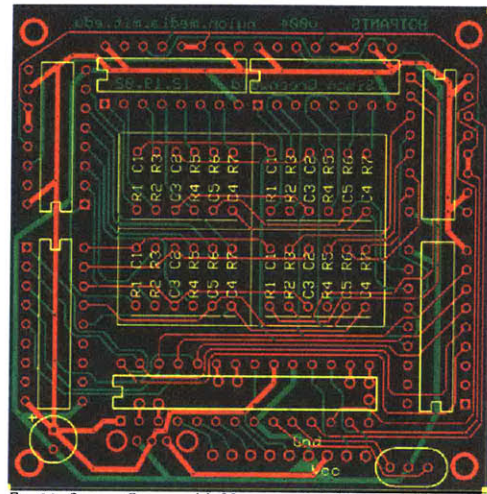


Fig 82: Simon Greenwold. Hotpants Pcb Layout

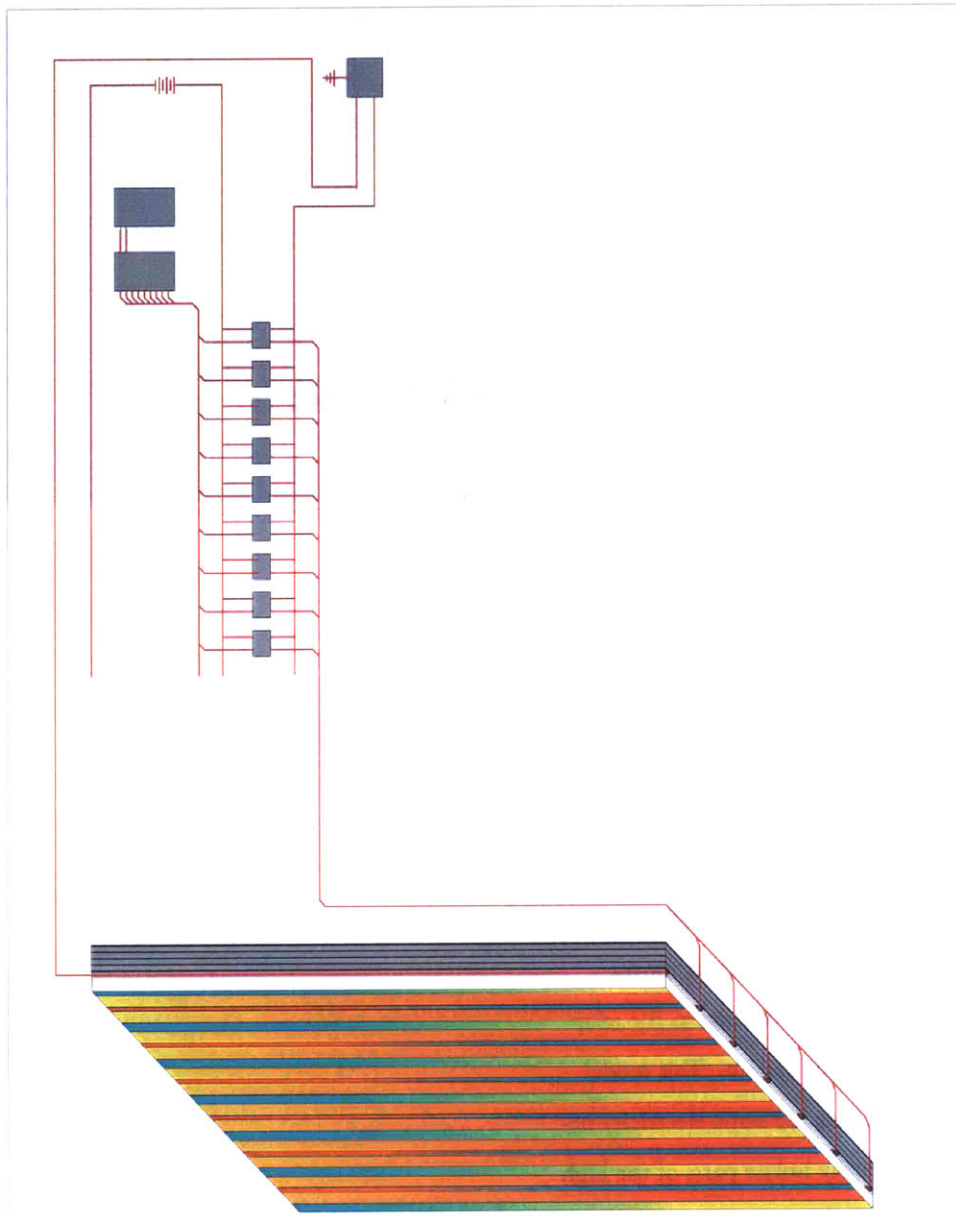


Fig 83: Lines Behind section/schematic

Lines Behind

Lines Behind uses thermo-chromatic paint in conjunction with heating elements to create surfaces that slide between colors. thermo-chromatic paint works with liquid crystals that realign themselves when heated changing their appearance. Using a thermo-chromatic paint with a non-thermo chromatic paint creates a blend between two colors as the thermo-chromatic paint becomes transparent revealing the color below. The heating elements used in this project are 'off the shelf' electrical radiant floor systems (Fig 84). The linear vertical lines of the paint correspond to the linear elements of the heating system. The large amount of power needed to convert electricity into energy necessitates the use of an isolated high power line and series of relays.

The action of the system is tied to thermal mass of the backing board that the paint is applied on. The speed at which the paint itself can change color is a matter of moments (Fig 85), but natural rate of heat loss/gain of the thermal mass of the backing board gives the visual change an organic limitation. Above this limitation the rate of change is controlled via computer, either slowed down to below human perception or run as a steady pulsing rhythm. This pulsing of rhythmic is not unlike the visual pulsation created by the brain attempting to organize a perceptual ambiguous image and creates a similar disorienting sensation. The disorientation is enhanced by a natural misconception that the color changes are caused by lighting conditions. The change in temperature of the surface conjoined with the color adds a tactile element to the work.

There is a loss of precision between the digital and the ana-

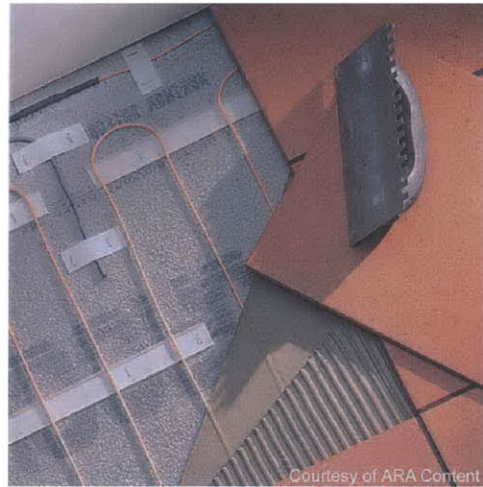


Fig 84: Comercial Electric heating system



Fig 85: Mood Rings

logue as the thermal mass of the backing board spreads heat away from the linear heating element. This bleeding action creates a visual complexity and needs to be considered in the design of applications for the surface. More detailed imagining would be presented in static paint that is then over painted with thermo-chromatic paint that disappears in the heat.

A two color thermo-chromatic paint system was chosen over the multicolor thermo-chromatic systems because of precision of heat necessary with more colors. If the engineering of the heating could be worked out to a great degree more color can be created using offset printing techniques to create color blending effects. Future research will include the incorporation of a visual feedback loop to check the color of the surface with the microcontroller.

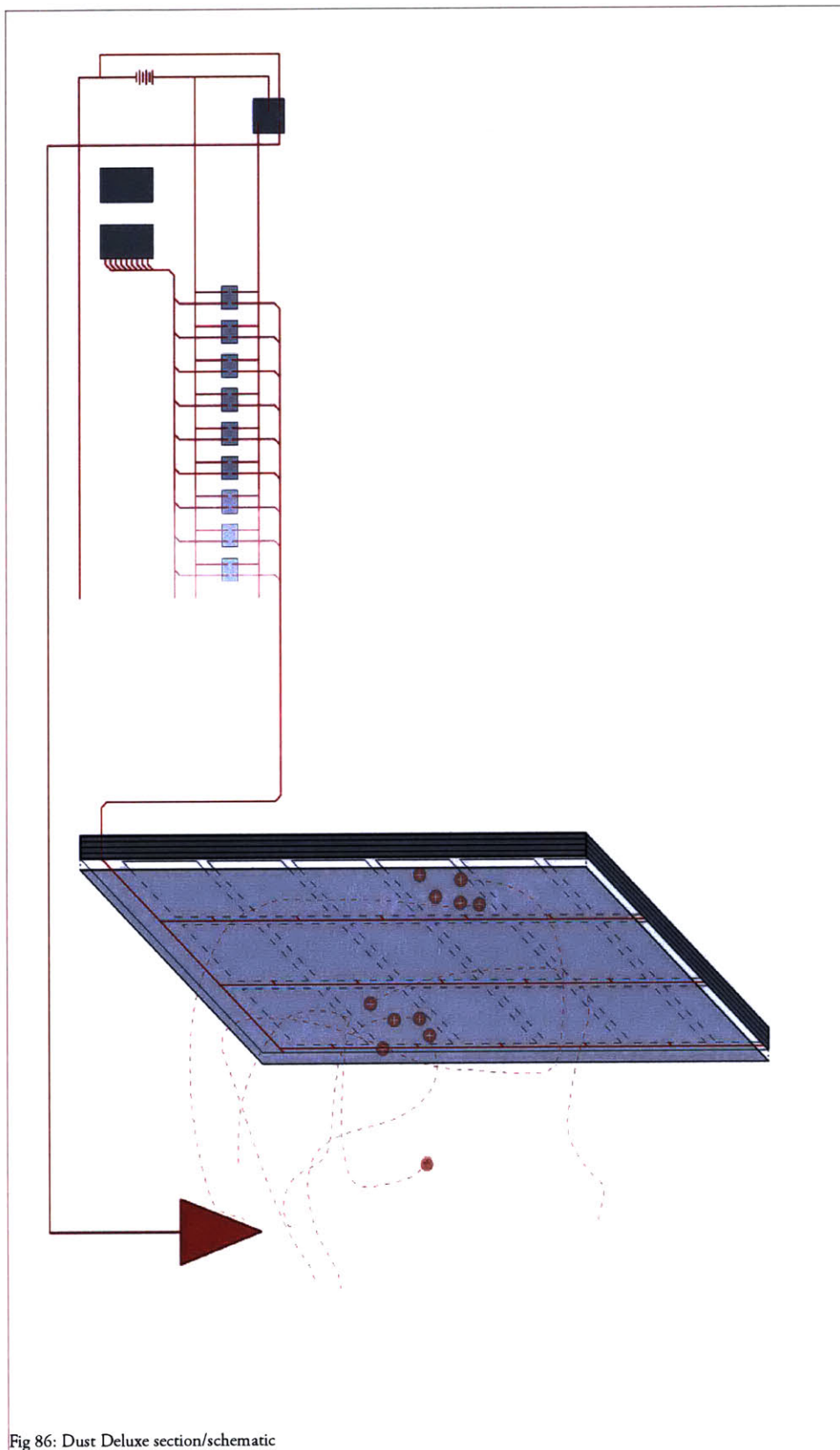


Fig 86: Dust Deluxe section/schematic

Dust Deluxe

This interface attracts dust to its surface to create image. A high voltage ion emitter is used to positively charges dust particles that then seek out the lowest electrical point in the room. Pixels on the surface of the wall are driven below ground to attract the dust. This same principal explains the dust that develops on television screens and is the basis of many air purification devices. The high voltage ion emitter is used to expedite the natural processes of dust attraction.

Dust has associations of size and time. Just on the border of visual perception in its size dust is felt in the eyes and lungs before it is revealed in bright light. Seen mainly through its accumulations rather than individual particles dust is trace of the movement of dust across a surface, stuck where there is lack of air movement. An artwork such as 'Dust Breeding' Man Ray's photo of Duchamp's critical work 'The Bride Stripped Bare by Her Bachelors, Even' covered with dust reveals not only the cracks in the glass surface but also show the amount of time the glass has not moved. In this way dust acts a physical instantiation of time, able to show processes that are slower than human perception. The image on Dust Deluxe at anytime would be only an instant of a changing process that could be seen through slow motion.

We see accumulations of dust but rarely individual specks, in a room dust is felt in the eyes and lungs before it is revealed in high contrast light. The dust seen on the surface is a record of the dust in the room during a time period showing dirt, pollen, and dander, all adding up to create image.



Fig 87: Man Ray, 'Dust Breeding'. 1920. photograph of Duchamp's critical work *The Bride Stripped Bare by Her Bachelors, Even* (1915-23).

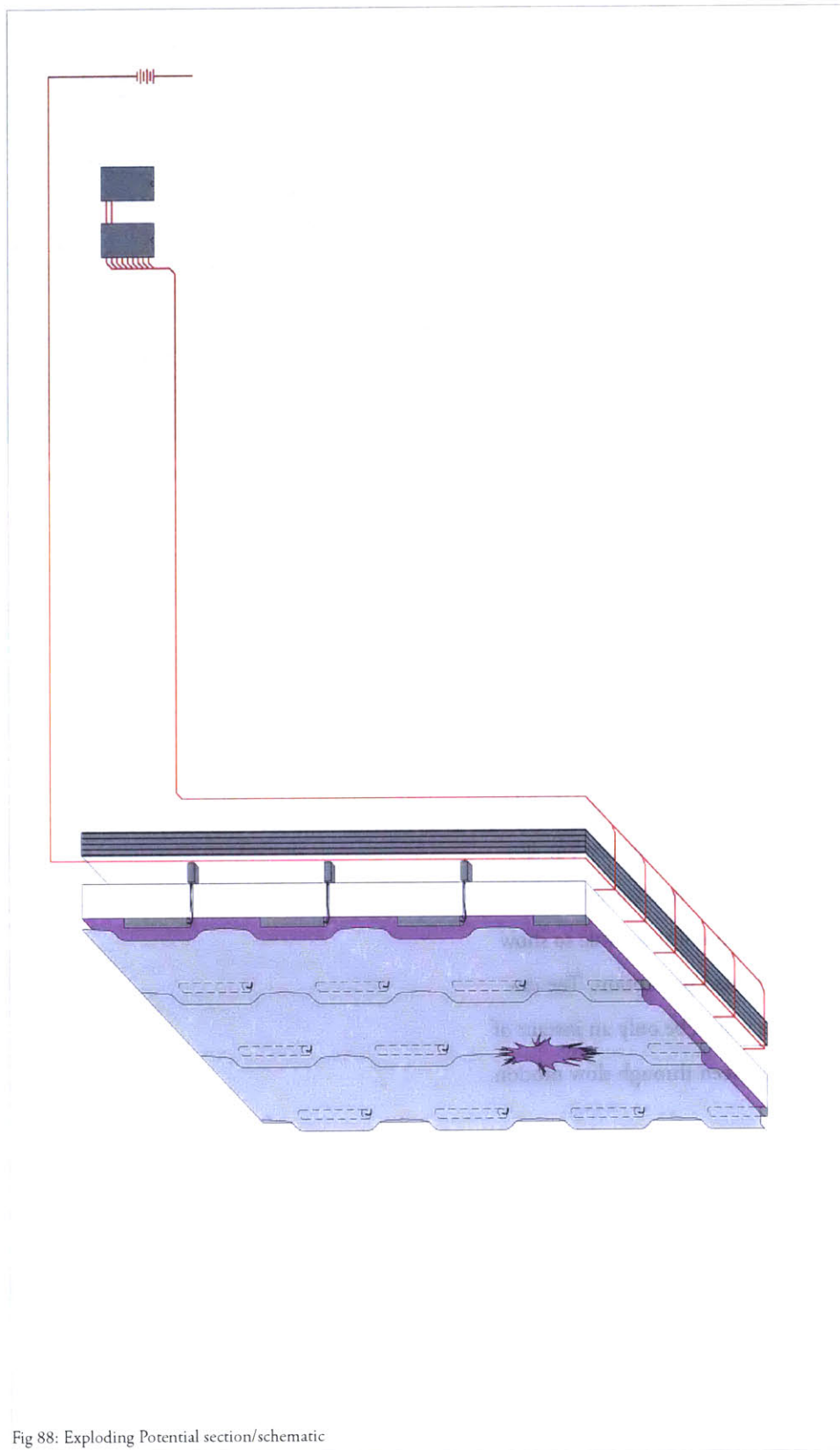


Fig 88: Exploding Potential section/schematic

Exploding Potential

Exploding potential uses gunpowder as surface actuation. Small “lady finger” firecrackers with computer controlled electric fuses are laminated between different colors of paper. Because most of the power in the system is generated by gunpowder the project does not need relay switches. Also it should be noted that after September 11th, electrical fuses require a license to purchase.

Figure 89 is a direct inspiration for the visual effect of the piece, the contrast of one color material busting through a second. The firecracker leverages a simple electrical pulse from the computer into an explosive force. The unpredictability of the explosion give the surface a complexity and beauty that acts as individual units of pattern.

While the actual explosion exists only as an instant of violent action, it is the anticipation of the event that is the key experience of the piece. The piece is conceived with the idea that the computer sets the explosives off randomly, forcing the viewer to stay on guard for danger. This piece is directly reactionary to the disconcerting nature of the contemporary 24 hour cable news cycles creating a heightened sense of anxiety. Anxiety that comes from knowing that something violent is going to happen but being unable to know or control, where or when.

Future development of this project will start with further consideration of the explosive elements between the layers. In the current drawing the explosives are organized into matrix. Consideration of individual explosions as the unit, the materials that create the sandwich inform the development of yardage.



Fig 89: Textile design. (Skin, 98)

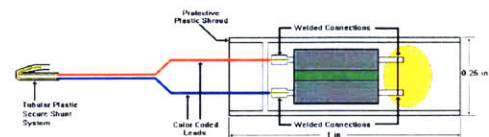


Fig 90: electrical fuse diagram.

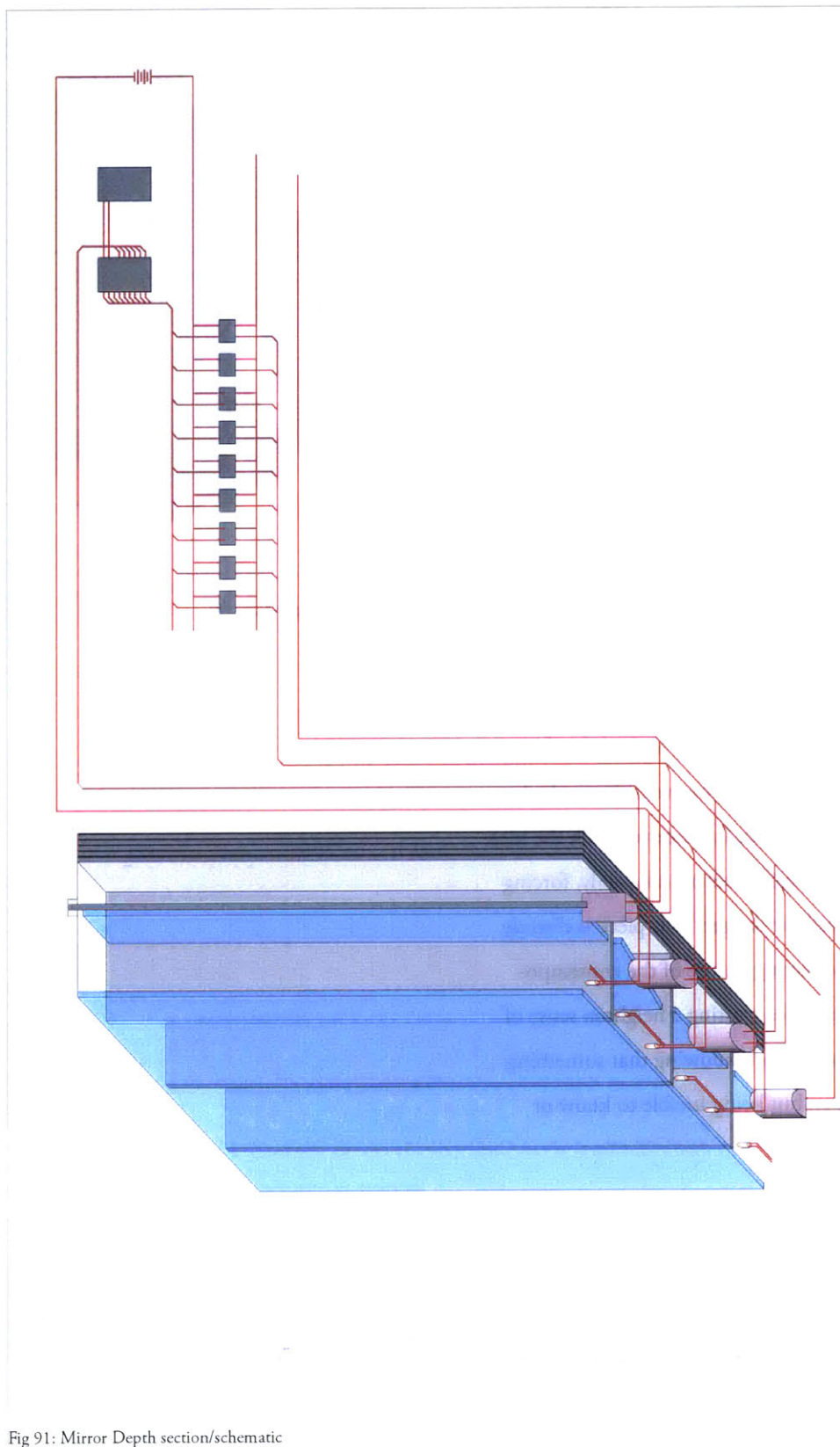


Fig 91: Mirror Depth section/schematic

Mirror Depth

Mirror depth uses a half silvered mirror and regular mirrors to create the illusion of an infinitely deep surface. The reflectivity of a half silvered (two-way) mirror is dependant on the lighting conditions on both sides of the mirror. If the side that has the silver is brighter then the other then it will act as a mirror, otherwise it will be transparent as a pane of glass. Facing this towards another mirror creates an infinite reflection that the viewer can see into. This effect has been used as disco clubs and can also be seen in the work of Yoyoi Kasuma (Fig 93). Creating an array of chambers behind the half silvered mirror that are individually lit, sections of the surface recede into infinity while others remain surface. Having the second mirrors on rotating motors the spaces created behind the surface will appear to curve off in different directions.

The appeal of this work is the relationship between depth and surface, creating space where none exists. Wile this work lacks delicacy in its current presentation it leverages itself on phenomenological experience.

In the current design the unit is drawn as the vertical striations of motor operated mirrors behind the glass. Future refinement of this design will look to to more sophisticated ways to control the light between the two surfaces creating an undulating surface of depth.

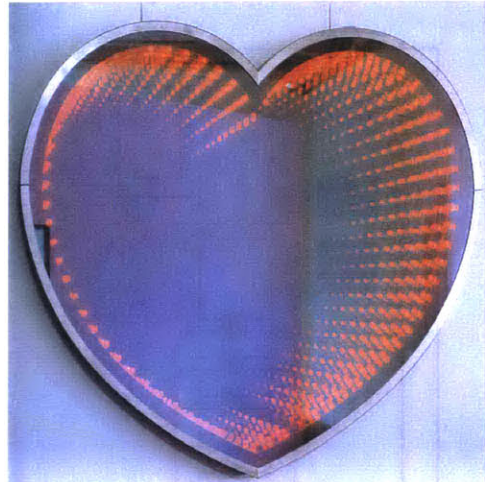


Fig 93: Yayoi Kusama. "God's Heart" 2000. New Century Le Consortium, Dijon.

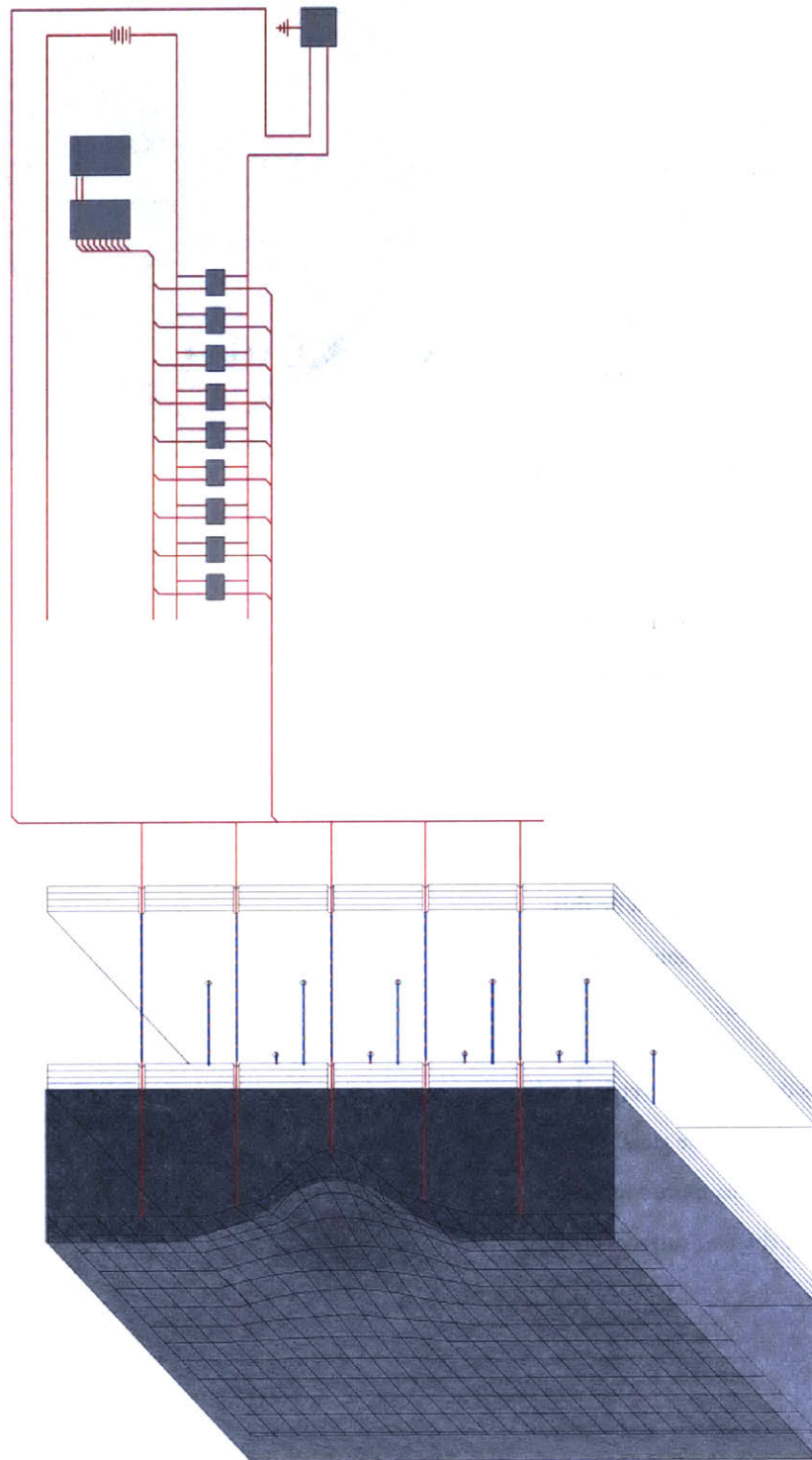


Fig 94: Felt Down section/schematic

Felt Down

Felt Down uses threads of shape memory alloy to create a soft surface that undulates on command. A shape memory alloy is a material that changes shape when current is applied; in this case it is a wire that contracts. A synthetic fabric net is cast into a thick hand felted surface during the felting process. The felt for this piece needs to be hand felted, as hand made felt results in a fluffy loose felt that has a consistency not unlike cotton batting while industrial felt is machined into a dense fabric. The fluffiness of the felt allows the surface to contract under the force of the shape memory alloy.

This project can be seen as an inversion of 'Aegis Hypo-surface' (Figs07, 08). 'Aegis Hyposurface' is cold, clean pistons, forcing a surface out at the viewer. Felt Down is s'oft, handmade, gently withdrawing itself from the viewer. The hand made felt surface encourages tactile engagement. The smooth "breathing" motion of the shape memory alloy gives the actuation of the project an organic feel. Shape memory alloys create no sound when they move adding to the claming experience of Felt Down

Future work on project will investigate the materiality of the surface through layering. Interweaving layers of material that does not contract within the felt batting that reveal themselves when the surface contracts. The engineering of the project will look at the details of the shape memory alloy; ensuring that they do not create a fire hazard with the heat that exert when contracting, also preventing them from breaking during tactile interaction from the viewer.



Fig 95: Handmade felt studies



Fig96: Handmade felt studies

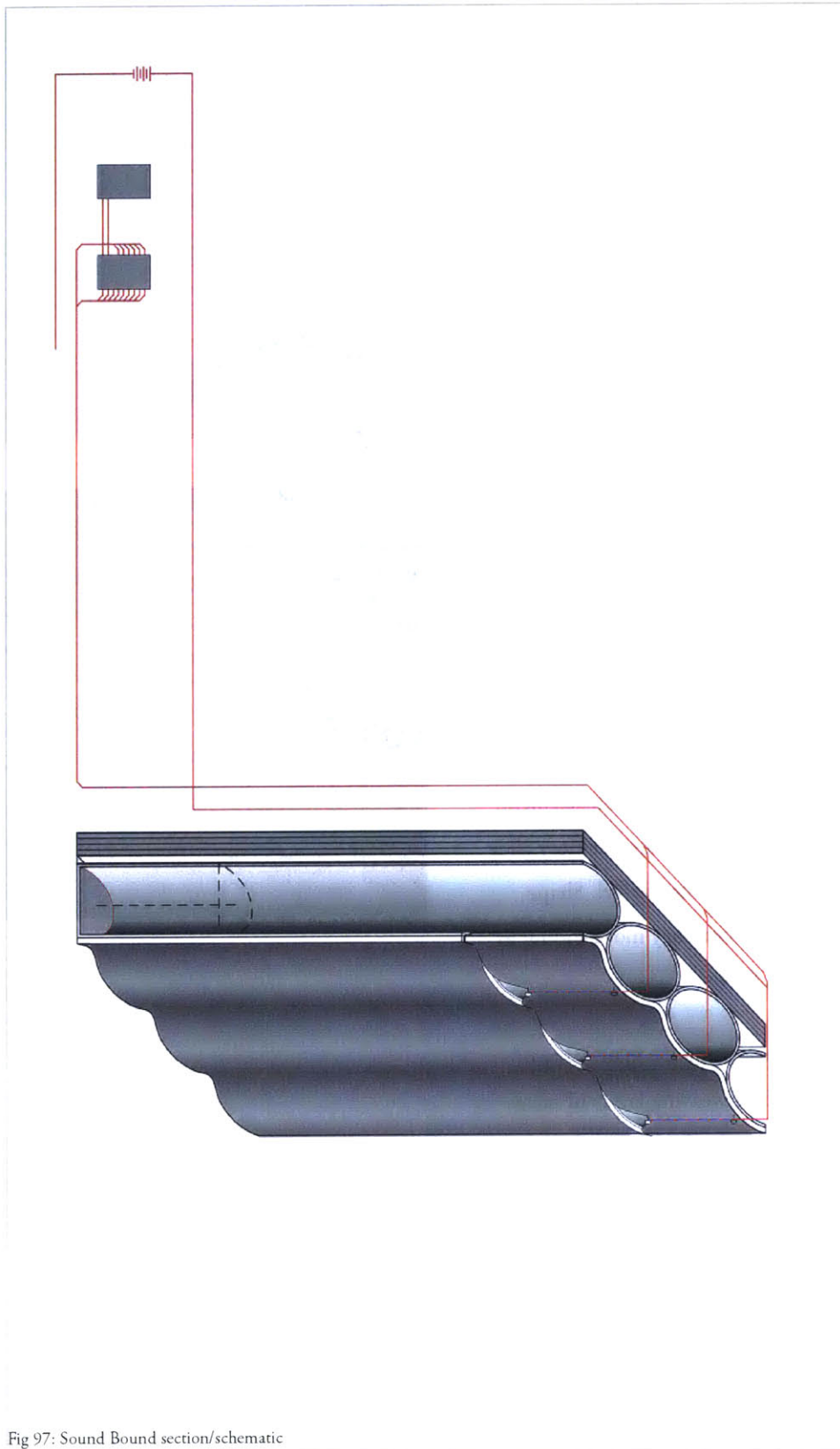


Fig 97: Sound Bound section/schematic

Soundbound

Soundbound conceives of an interactive surface that engages the viewer through audio means. Behind a felt surface are a series of empty tubes act as helmholtz resonators. A helmholtz resonator is an empty container with a single opening. The space of the container is tuned to resonate at a specific frequency. When the same frequency is played in the air outside of this container, the air inside will vibrate, creating a standing wave and amplifying that frequency above others. This same idea is how sound is made with an empty bottle. The thick surface of industrial felt in front of these resonators has a series of slits cut into it. Shape memory alloy threads are used to silently open these slits and play the resonances of the containers. Opening the slits one plays the resonances similar to holding down the pedals and lightly pressing the keys on a piano.

Resonance is one of the ways that we understand the size of the space. For example standing in an echoless anechoic chamber gives a feeling of claustrophobia, or a long sustained echo expresses the monumentality of a cathedral. The use of resonating containers in architecture can be traced to the ancient Romans who would bury clay pots in the walls and floors of a amphitheater to change the sound of the space. By adding ash to the pots the sound can be tuned to different frequencies. Future development of this work will allow the idea of pattern to influence the opening in felt surface. Rather than only creating a row of slits in the surface, cutting a field of slits creates an expandable surface. These cuts will be further developed via principals of surface design creating surfaces that moves between a solid plane and an open lacework.

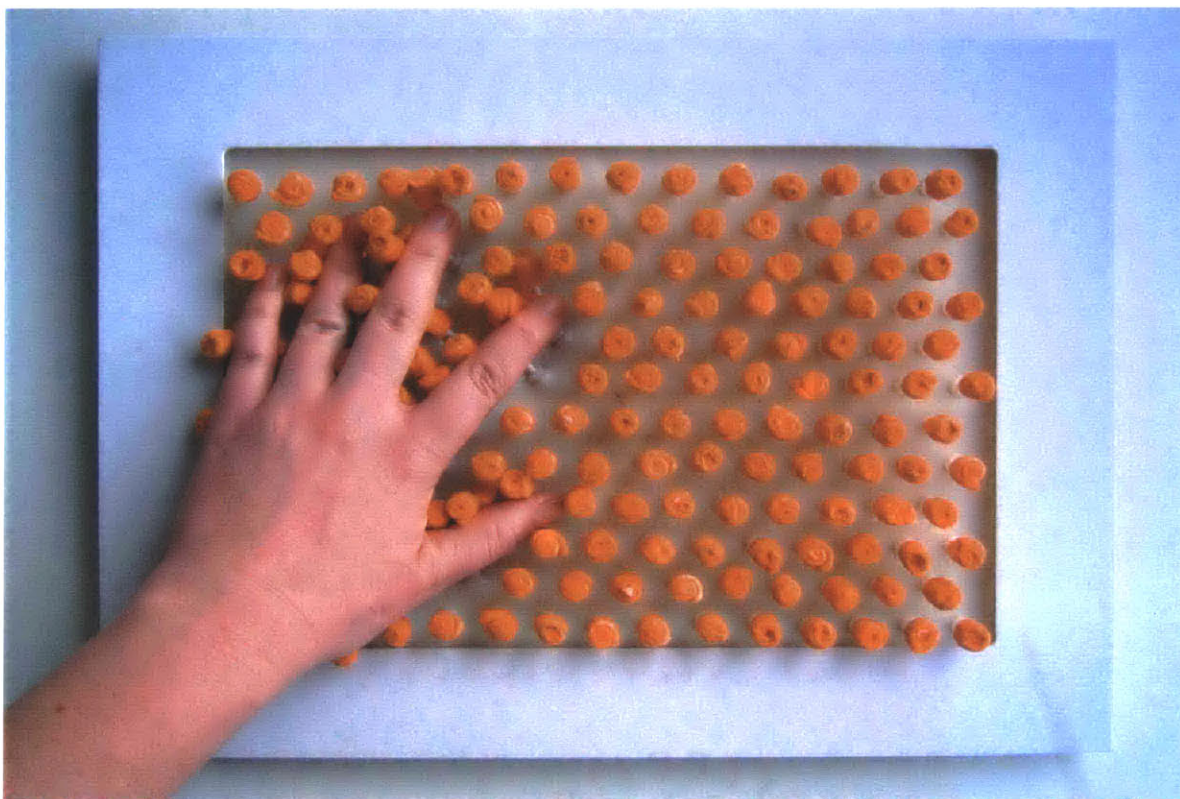


Fig 98: Super Cilia Skin Prototype (image Hayes Raffle)

Super Cilia Skin

Super Cilia Skin is a computationally enhanced membrane that serves as both input and out. This project was designed and developed by Hayes Raffle, Mitchell Joachim, and myself with the support of the Tangible Media Group at MIT. SCS borrows the term “skin” from the biological world for its implications of an exterior membrane as well as the sense of touch is able to both sense and manipulate the environment. Interpersonal multimodal communication was one of the main design criteria in this project and reflects in the project's development.

The surface of super cilia skin consists of an array of felt-tipped actuators (cilia). These cilia pierce an elastic membrane and are capped with small magnets beneath. Below this membrane is an array of computer-controlled electro-



Fig 99: Wind across a field (image Hayes Raffle)

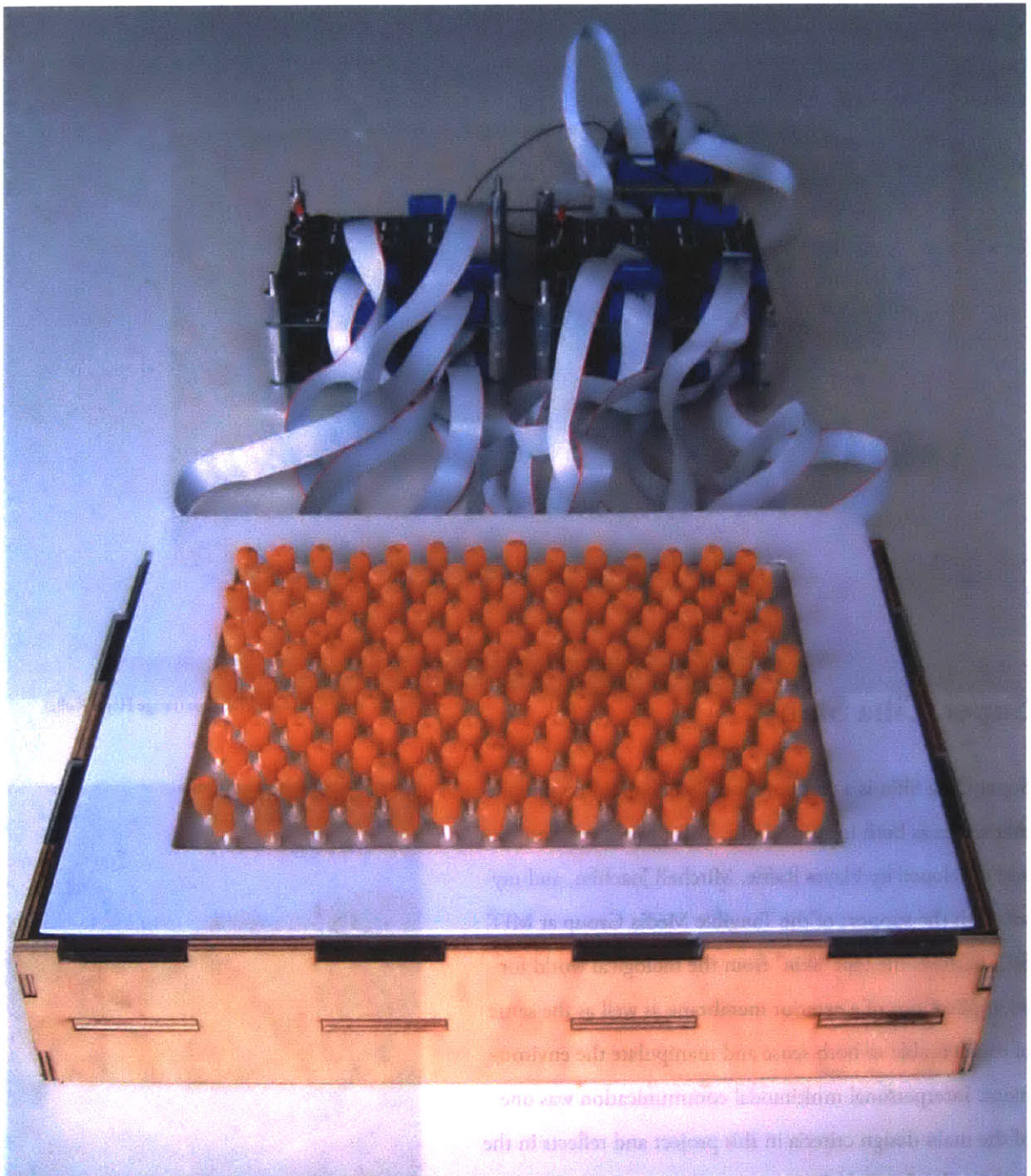


Fig 100: Super Cilia Skin Prototype (image Hayes Raffle)

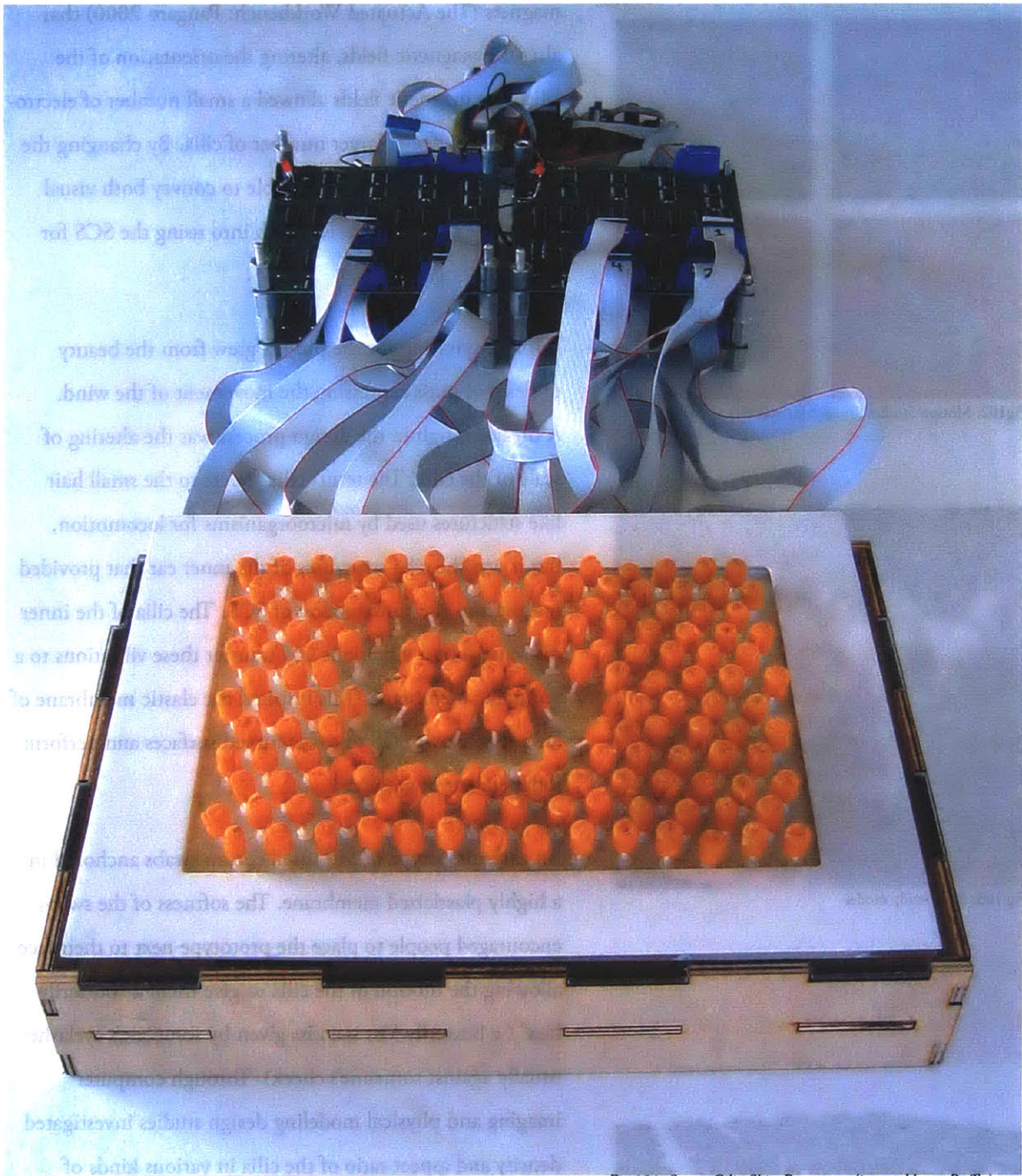


Fig 101: Super Cilia Skin Prototype (image Hayes Raffle)

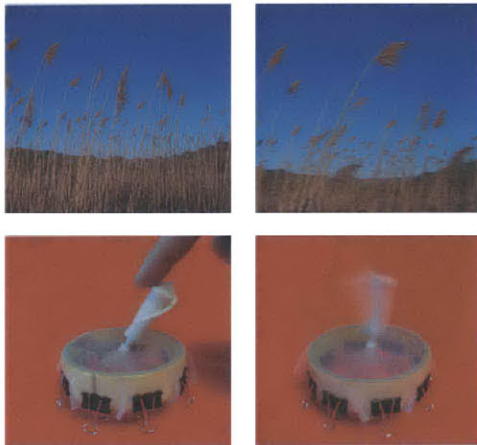


Fig102: Motion Studies (image Hayes Raffae)



Fig 103: Early study model

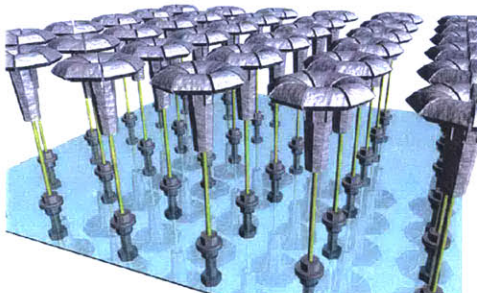


Fig 104: Early study model (image Mitchell Joachim)

magnets (The Actuated Workbench: Pangaro 2000) that alter the magnetic fields, altering the orientation of the cilia. The magnetic fields allowed a small number of electromagnets to effect a larger number of cilia. By changing the orientation of the cilia SCS is able to convey both visual and tactile information. Research into using the SCS for sensing is ongoing.

Initial inspiration for the project grew from the beauty of fields of grass expressing the movement of the wind. A breakthrough in the design process was the altering of scale of the cilia. The term “cilia” refers to the small hair like structures used by microorganisms for locomotion, but it was the cilia structures of the inner ear that provided insight into the construction of SCS. The cilia of the inner ear sense sound vibrations and transfer these vibrations to a tympanic membrane. This inspired the elastic membrane of SCS that allows SCS to cover curved surfaces and perform independent of gravity.

An early prototype of SCS used cotton swabs anchored in a highly plasticized membrane. The softness of the swabs encouraged people to place the prototype next to their face allowing the motion of the cilia to give them a “butterfly kiss” (a butterfly kiss is a kiss given by someone’s eyelashes usually against someone’s cheek). Through computer imaging and physical modeling design studies investigated density and aspect ratio of the cilia in various kinds of membranes. The prototype used cilia slightly smaller than our fingers with a 50% density, this gave a “good feel” to the surface.

The value of touch in communication technology and

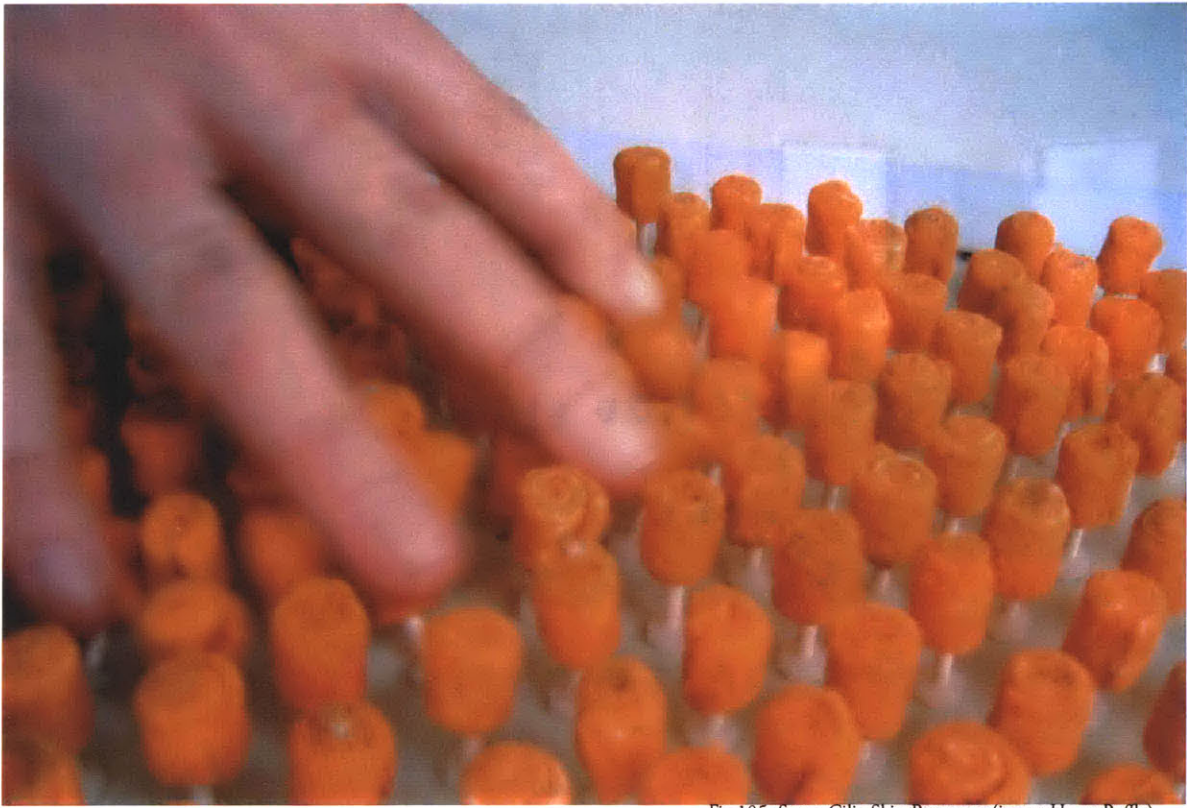


Fig 105: Super Cilia Skin Prototype (image Hayes Raffle)

education are two of main interests of the Tangible Media Group at MIT. SCS was designed to surface curved objects with an intent of using the surface on children's toys. Figure 106 presents an image of SCS on a Teddy Bear with an expressive stomach. The value of tactile and multimodal learning on early childhood education is well documented. While the current prototype is a long way away from this rendering of a bear further research could create interactive toys that move beyond bells and whistles.

The visual texture of tracks of a vacuum cleaner across shag carpet resonated as an early concept for SCS. As a medium of interaction, the floor plane is enticing because it is spatially connected to maps and human activity, and the floor registers regular tactile input from people's movement.



Fig 106: Teddy Bear study



Fig 107: Super Cilia Skin as floor system

As a carpet, SCS might record or replay footsteps over its surface. One could imagine two linked floors allowing an inhabitant to see the movement of people on the remote floor miles away. Such a carpet redefines the architecture around it as conflicted rooms become tactilely linked: mismatched floor plans would be revealed as ghostly footprints walk across the floor and disappear into a wall as a record of remote passersby walking across a larger space. SCS in a public space could compress time and, in a matter of minutes, replay days or months of people's movements. Patterns of ebb flow would appear as the surface creates a full scale visual and tactile Koyaanisqatsi, experience (Koyaanisqatsi 1982).

Presenting large scale dynamic phenomena such as the weather pattern of the United States, SCS reduces the scale of motion from kilometers to millimeters. As an informa-

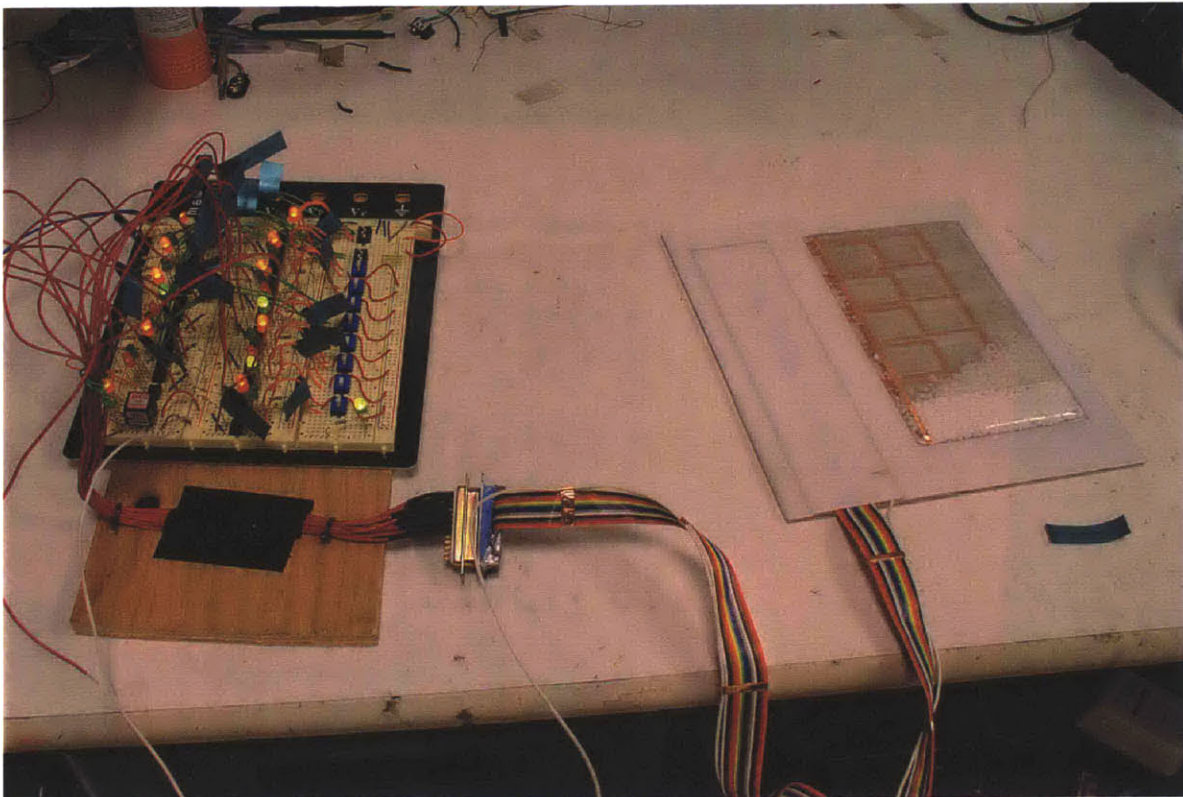
tion display, forecasts could be communicated in a subtle and continuous manner. While lying on the floor, the motion of the jet stream would gain new meaning as the turbulent wind gives a calming massage.

While investigating sensing methods with our prototype, we found that movements of the cilia generate electrical power in the Actuated Workbench. Although we were investigating sensing techniques, we realized we could store this power for later use. We imagined SCS as an exterior skin on skyscrapers that could both visualize information as a billboard size display and the harness energy of wind forces that blow over the building's façade.

The idea that an alternative energy source can be a visually engaging material rather than a highly engineered object could increase the market for alternative energy. Rather than relying on a moralistic desire to tread less heavily on the earth, an SCS alternative energy façade would also be appealing for its strong visual character. The façade would take wind energy as its input and use pictorial output to reflect current fashions or display advertising. This model challenges the traditional function of a building's skin as a barrier to protect people from the forces of their environment, and presents the architectural skin as a membrane that can transform the forces of nature into the energy required to support the building's inhabitants and the artificial nature of its interior. As provocative as these ideas may be, further investigation showed that they are not viable with our current prototype. But continuing research and development may allow for a surface that can harness the physical motions of the environment, turning the building into an active part of its ecosystem.



Fig 108: Super Cilia Skin as facade



Snow Screen

Fig 109: Snow Screen Prototype

Snow Screen uses high voltage static electricity to create an addressable opacity surface. Two sheets of transparent plexi glass are held $\frac{1}{4}$ " apart, the space in between contains small Styrofoam balls. On one sheet a matrix of 1" x 1" pixels are created out of indium tin oxide (a transparent conductive plastic) on the other sheet the full surface is covered with the same indium tin oxide. By sending one of the pixels to 1,200 volts, and the backing sheet to ground, a static electric field is created between these two planes, holding the Styrofoam in place. The Snow Screen is designed as a vertical wall system that takes advantage of gravity. In its current prototype to needs to be shaken to move the particles into the static electrical fields, but in future prototypes this action will be replaced by electrical fans.

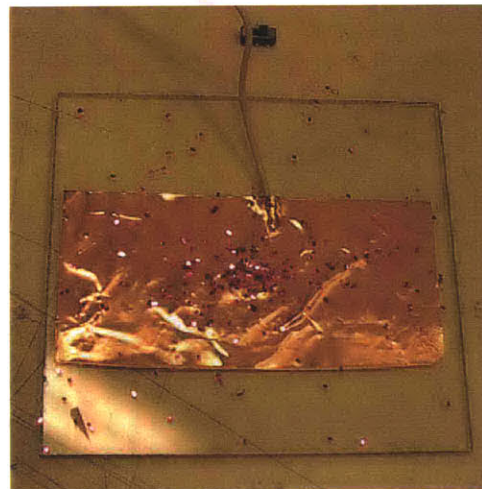


Fig 110: Early study model

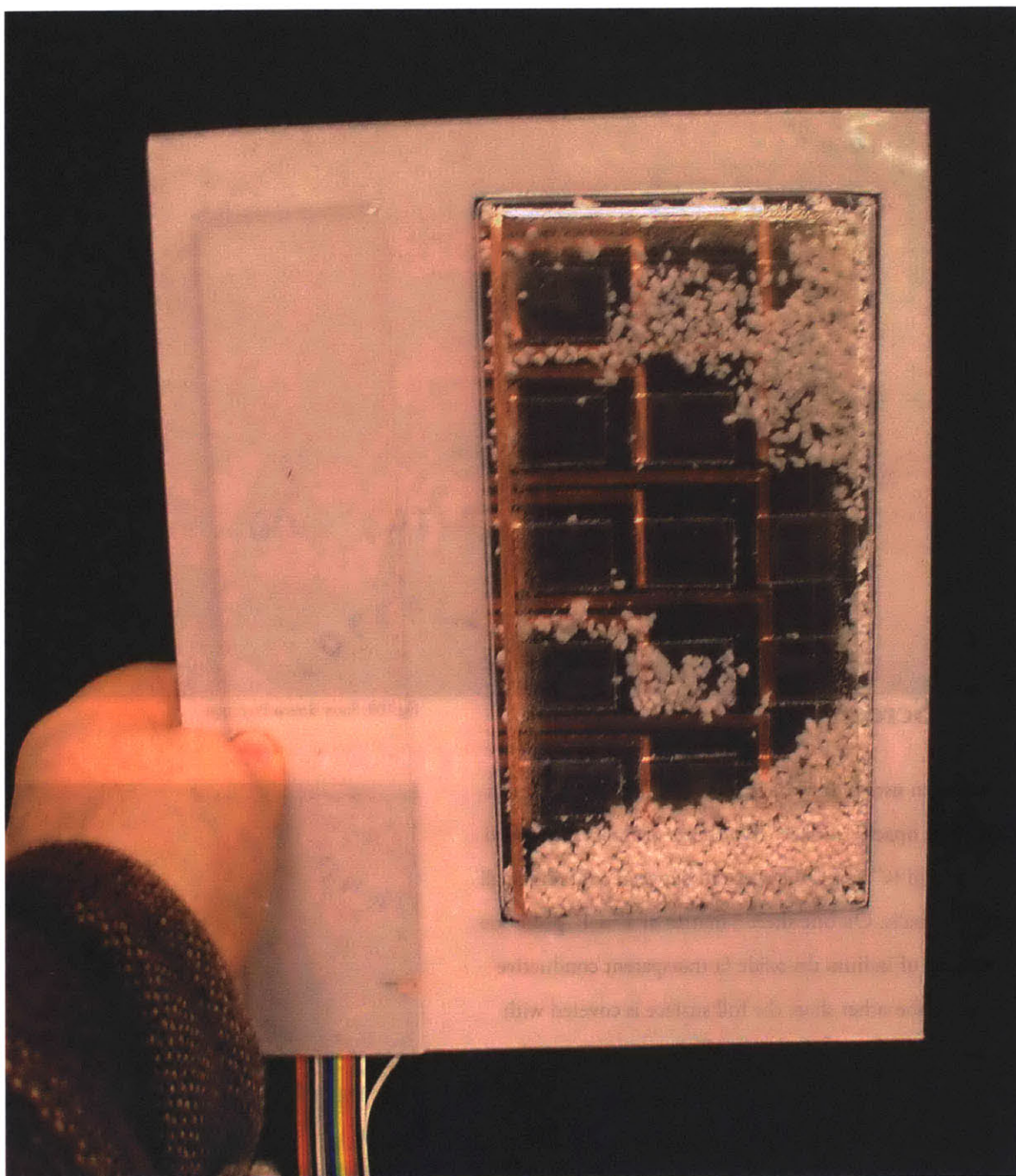


Fig 111: Snow Screen Prototype

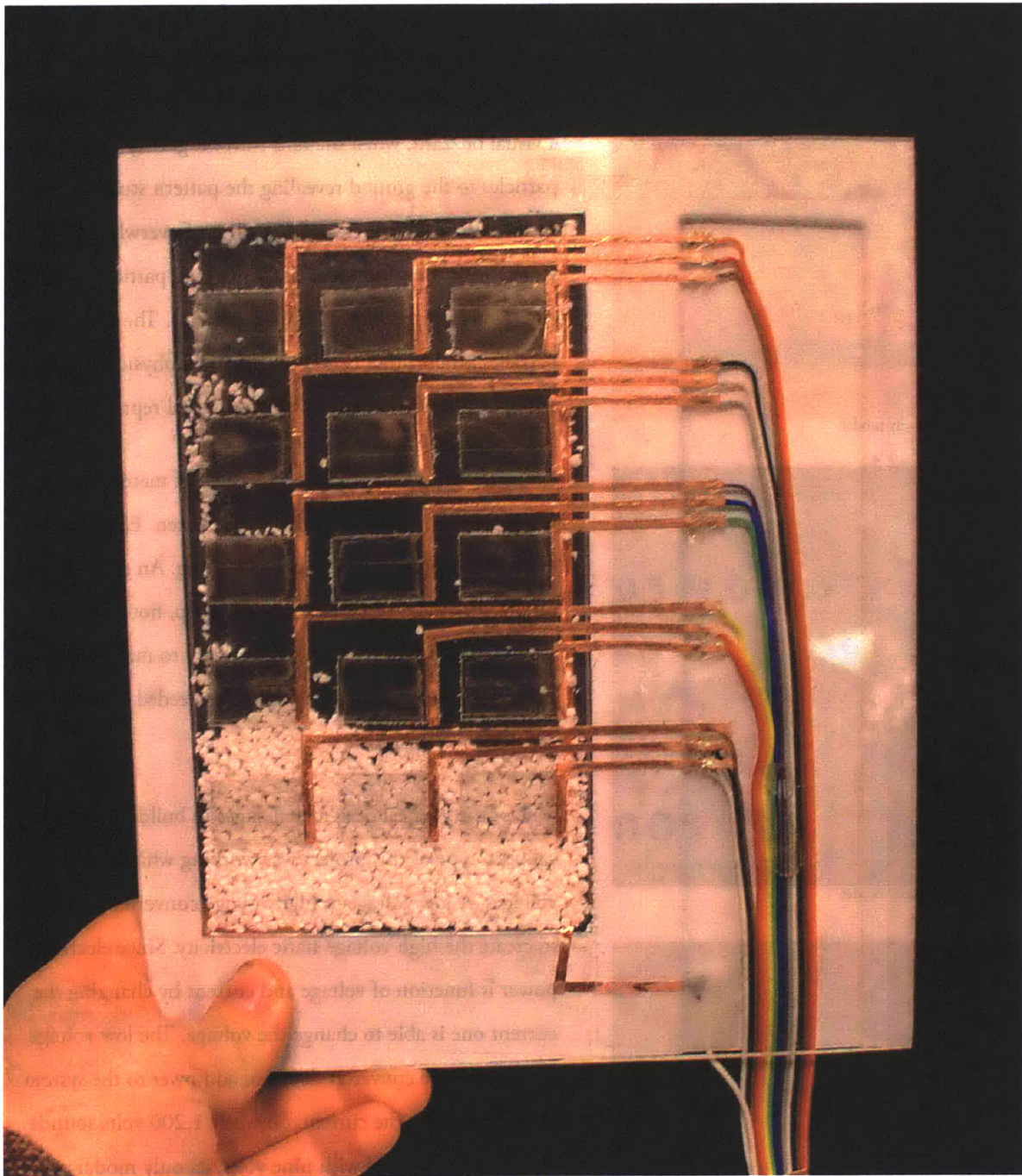


Fig 112: Snow Screen Prototype

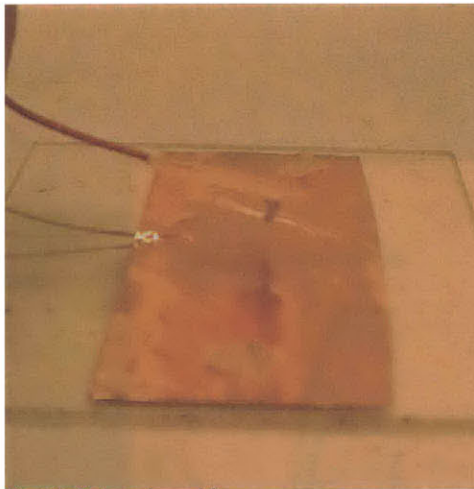


Fig 113: Early study model



Fig 114: Early study model

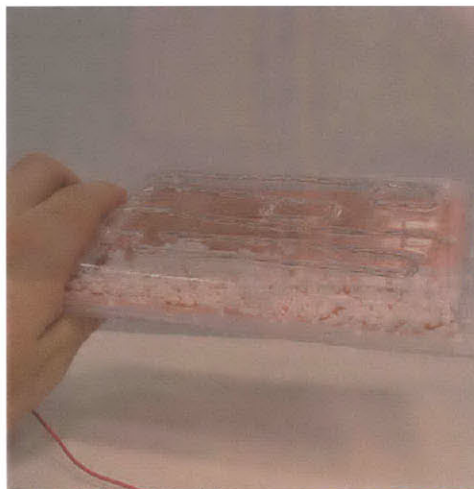


Fig 115: Early study model

The Snow Screen is inspired in part by the action of snow globes or simply snow. The system has two distinct states. When the fan is on the Styrofoam particles flurry creating a visual blizzard, when the fans turn off gravity pulls loose particles to the ground revealing the pattern stuck on the surface. Visually this creates a rhythm of overwhelming the viewer with the complexity of the flowing particles and an emerging order or pattern from this chaos. The Styrofoam particles arrange themselves to their own physical logic, adding a physical complexity to the digital representation.

In the design of the prototype a variety of materials were tested to fill the interior of the Snow Screen. Early studies looked at small scraps of paper and string. An early study model attempted to make string stand up, not unlike a the Super Cilia Skin, but the force necessary to make the string stand was much greater then the force needed to hold the Styrofoam in position.

One of the greatest design challenges in building the physical prototype of this project was working with the high voltages. A low voltage to high voltage converter was used to create the high voltage static electricity. Since electrical power is function of voltage and current by changing the current one is able to change the voltage. The low voltage to high voltage converter does not add power to the system rather it reduces the current. So while 1,200 volts sounds dangerous compared with nine volts, its only moderately dangerous since the power of the system runs off a nine volt battery. In fact when rubbing ones feet on the carpet on a dry winter day people are able to generate voltages above 2,000 volts and higher. The biggest danger with large voltages comes from the electrical arcs created at that voltage.

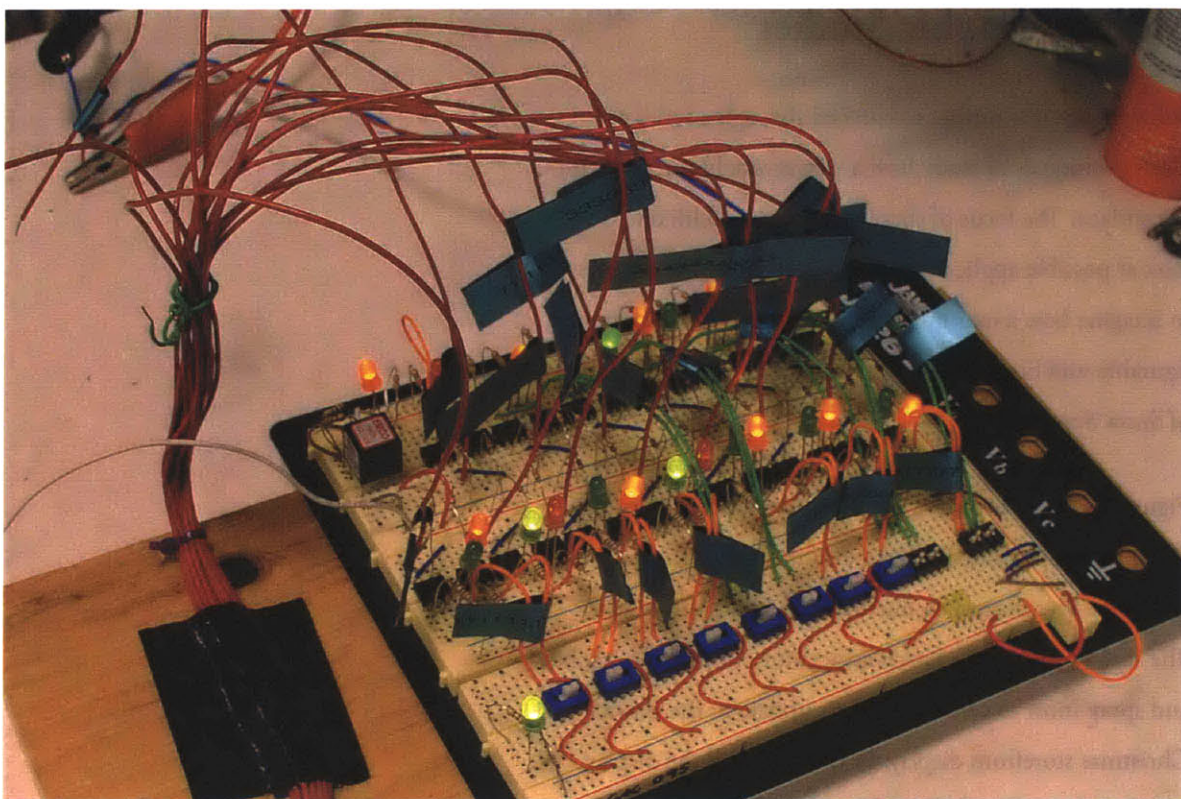


Fig 116: Snow Screen Prototype

The study of high voltage static electricity is more of a study of fields than flows. At high voltages electricity is able to jump across large distances of air, this necessitates electrical isolating of the wiring of the device. If two wires become too close they electricity will arc and their voltages will be identical. Individual optical relays were used isolate the high voltage from affecting the low 'control' voltages.

Motion Graphic Studies

Snow Screen was further researched through a series of Flash prototypes to study how a viewer would interact with the surface. The focus of these studies is twofold; one is to look at possible applications of Snow Screen. The other is to imagine how a user might interact, not just with a reconfigurable wall but with one with the specific physical nature of Snow Screen.

Figures 117 and 118 show stills from an animation of the Snow Screen presented as a storefront display. The first still shows the Styrofoam in a flurried state filling the window. The second pushes the kitsch associations of the snow globe and spray snow to create a modern update of the classic Christmas storefront display. In the third still the display has reconfigured to display advertising text. Finally the display mimics the profile of a passing shopper.

Figures 119, 120 and 121 show possible interaction strategies that emphasize the variable opacity of Snow Screen. In Figure 119 five individual sections of Snow Screen allow parts of the surface to be in different states of action. Using a capacitive sensor the surface would stop 'flurrying' and fall calm from a prolonged touch, leaving a trace of the touch on the surface. Figure 120 imagines a vision tracking system incorporated into the system that causes the snow to trace the skyline for a single vantage point flattening space into a plane. Figure 121 assumes the fully opaque surface as the starting point, as the user wipes away the surface the electricity releases the Styrofoam creating view through the surface, not unlike wiping away a foggy mirror to shave.

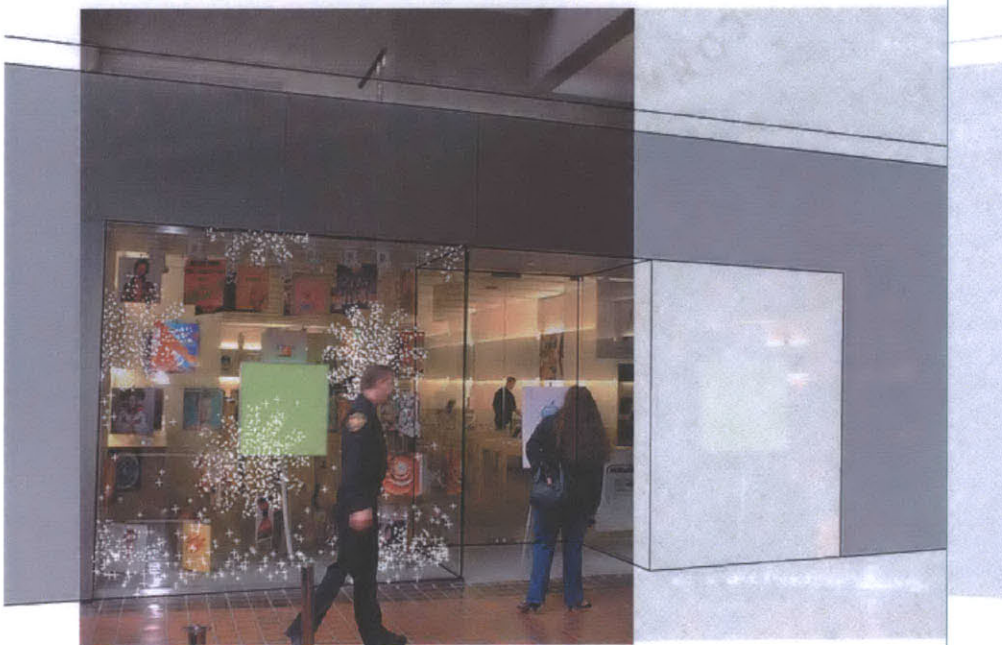


Fig 117: Snow Screen Interaction Study



Fig 118: Snow Screen Interaction Study



Fig 119: Snow Screen Interaction Study

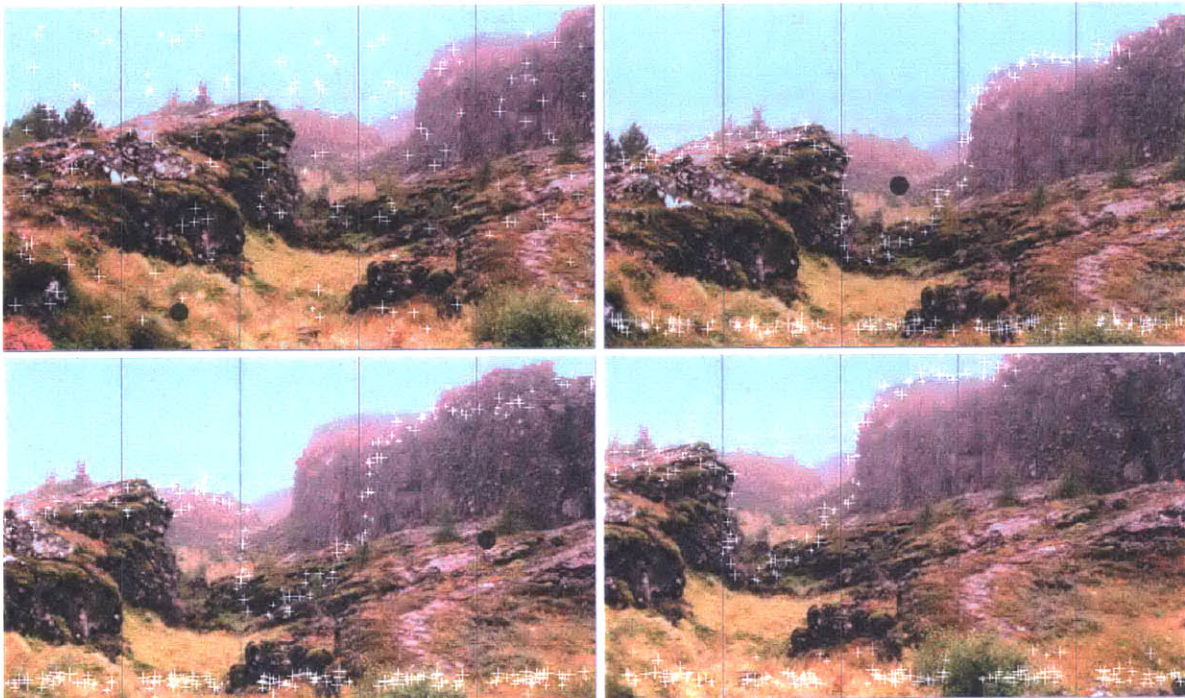


Fig 120: Snow Screen Interaction Study

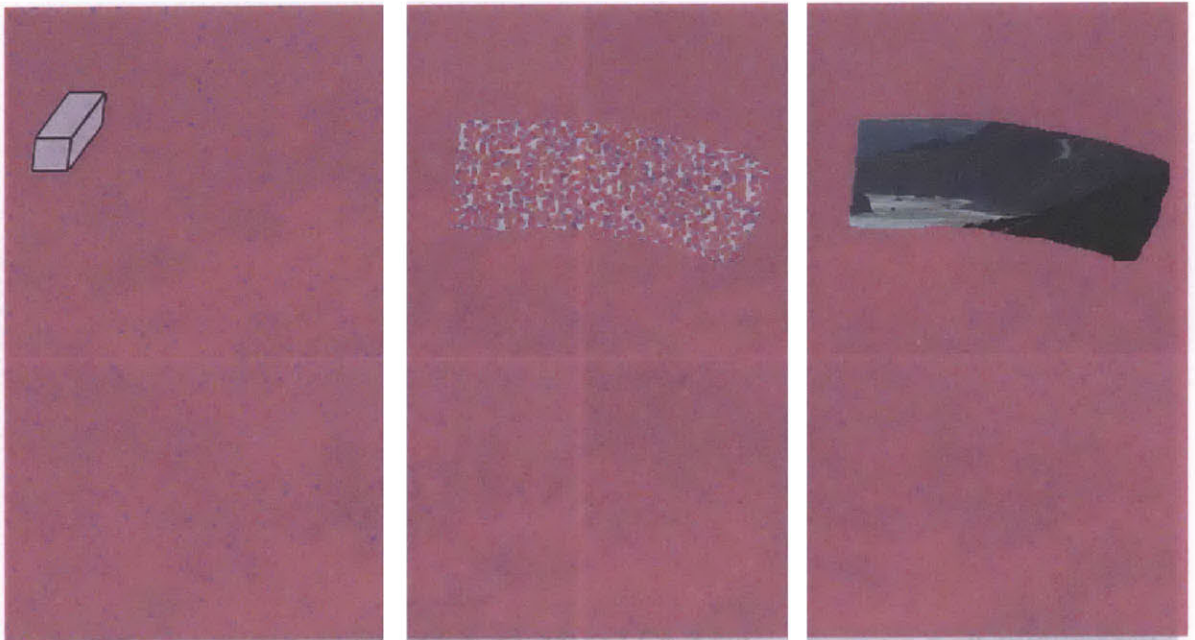
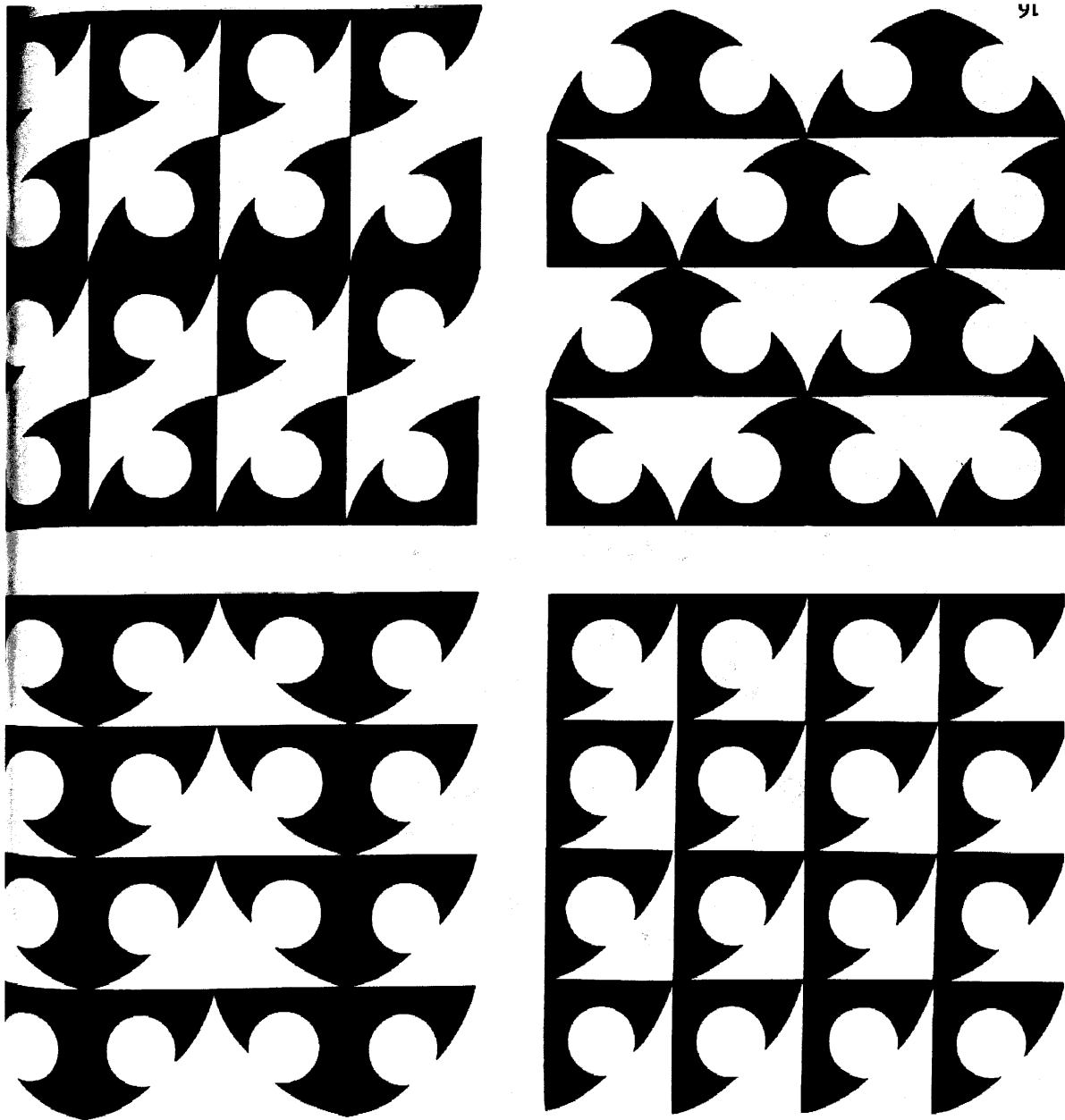


Fig 121: Snow Screen Interaction Study



The studies of interaction do not reflect a way of thinking about surface seen in the decorative arts. The next series of motion graphic studies used Figure 122 as a starting point to imagine patterns in motion. This pattern was chosen because of the variety seen in the yardage made from a simple unit. These studies attempted to think of patterns in motion through the terminology of unit and yardage to

Fig 122: Norma Beale. Cut paper design. (Principles of Pattern, 69)

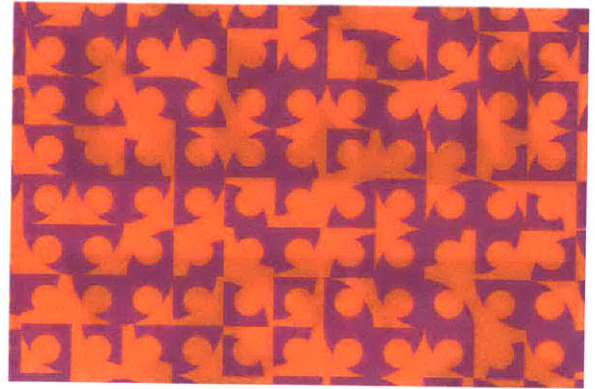
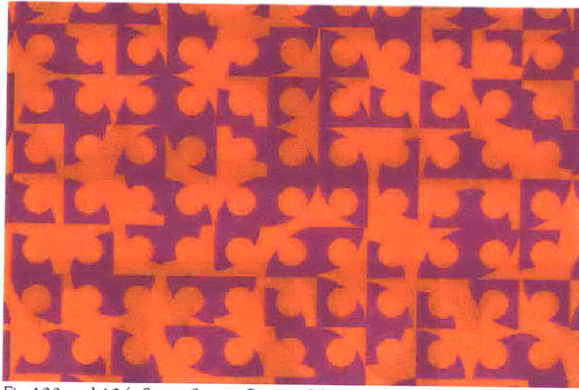
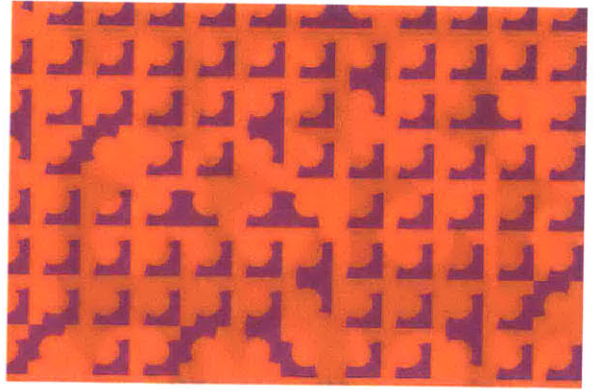
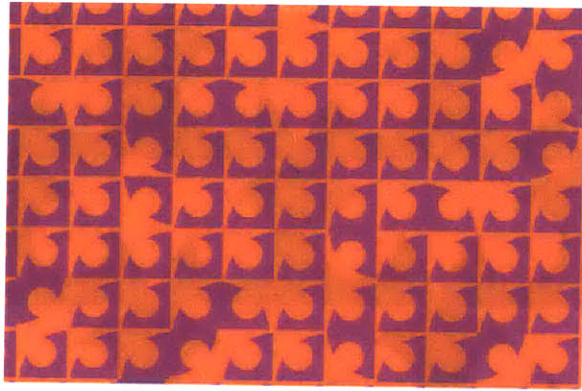
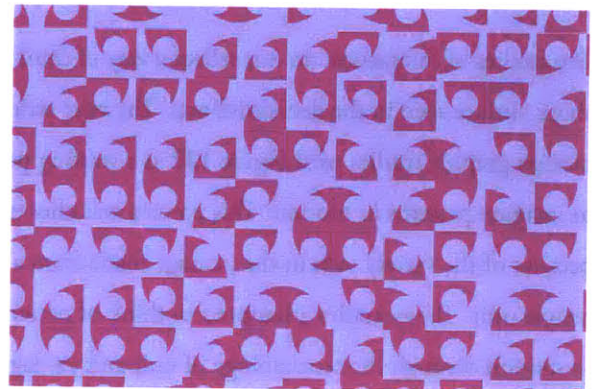
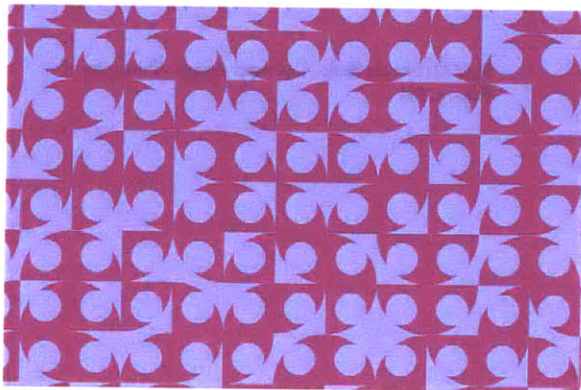
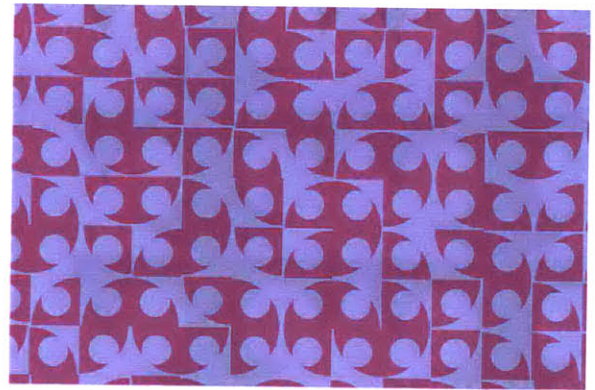
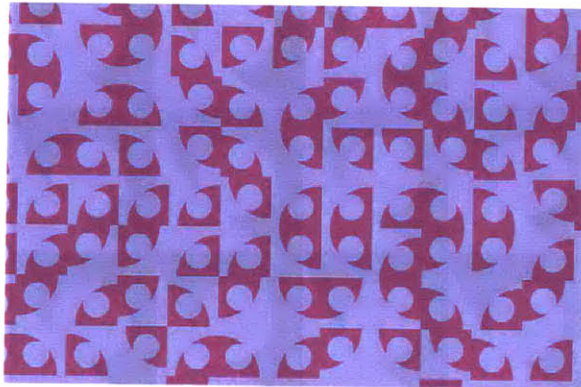


Fig 123 and 124: Snow Screen Pattern Motion Studies



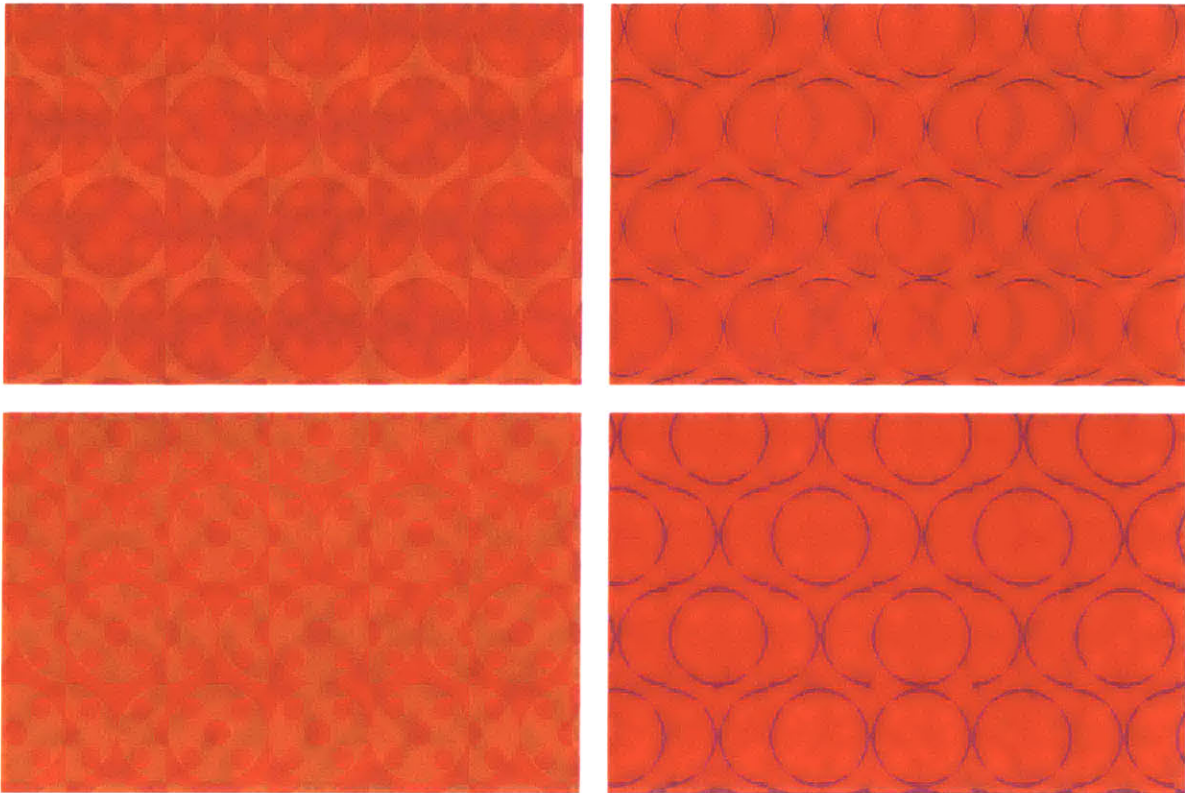


Fig 125 Snow Screen Pattern Motion Study

avoid the computer graphics imagery of screen savers. The internal structure of movie clips in Flash allowed a variety of properties to be studied in motion; from color to size to rotation. Figure 130 uses texture to represent the physical elements of the Snow Screen.

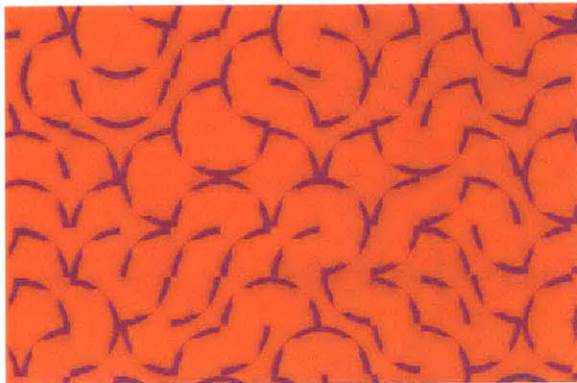
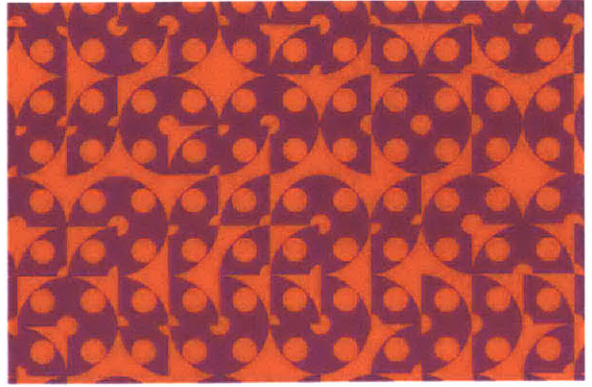
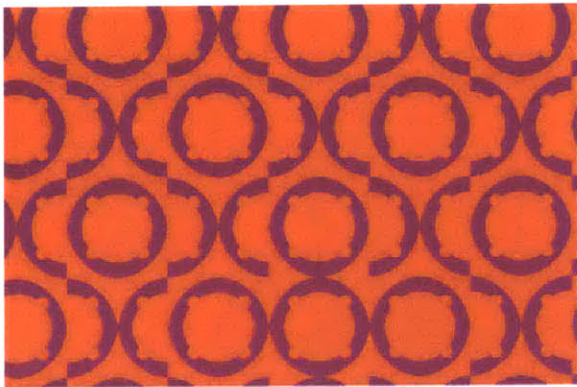
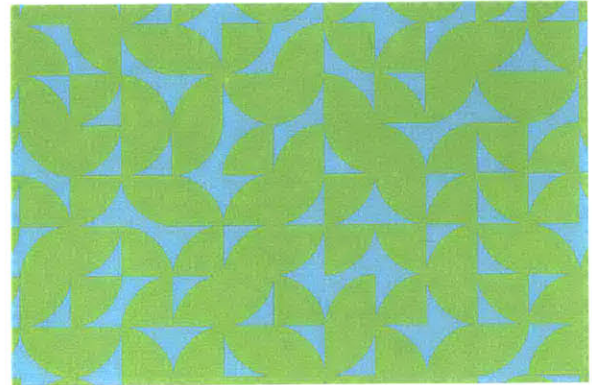
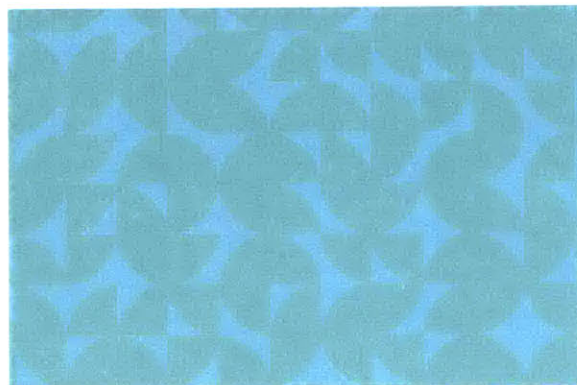
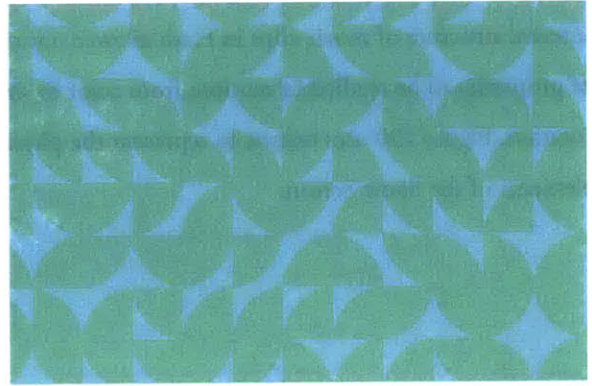
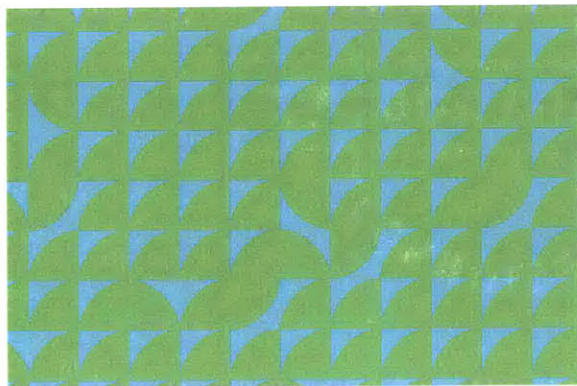


Fig 126 and 127: Snow Screen Pattern Motion Studies



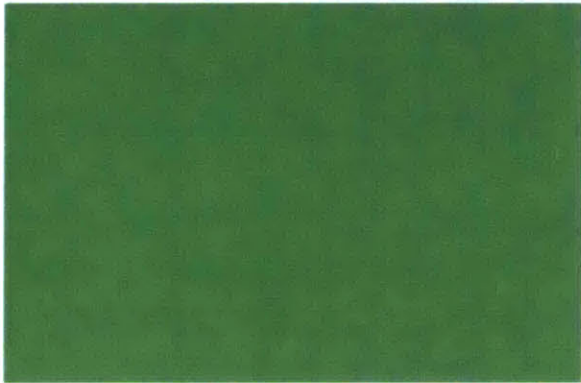
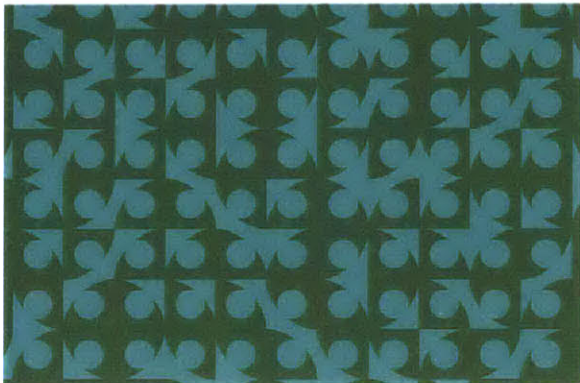
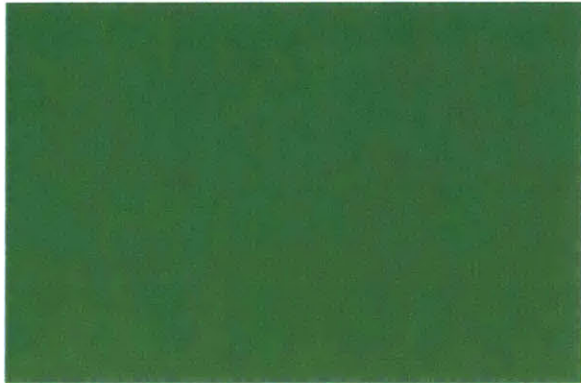
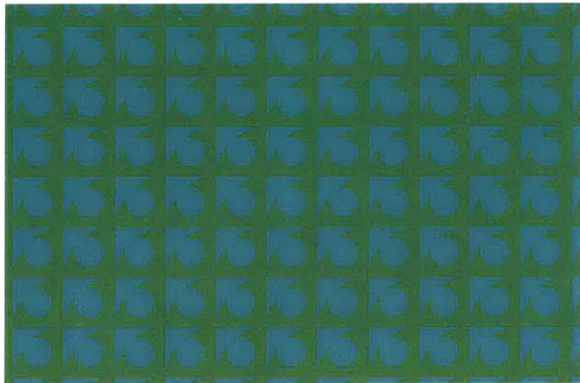


Fig 128 Snow Screen Pattern Motion Study

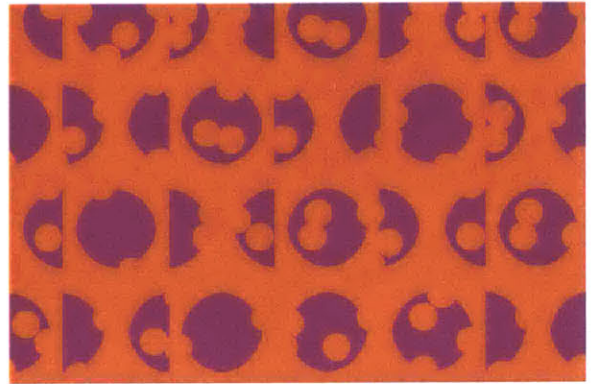
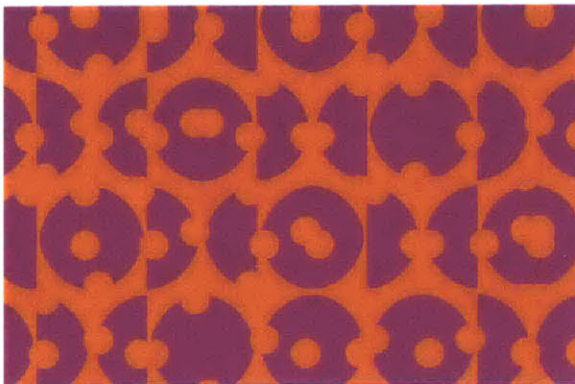
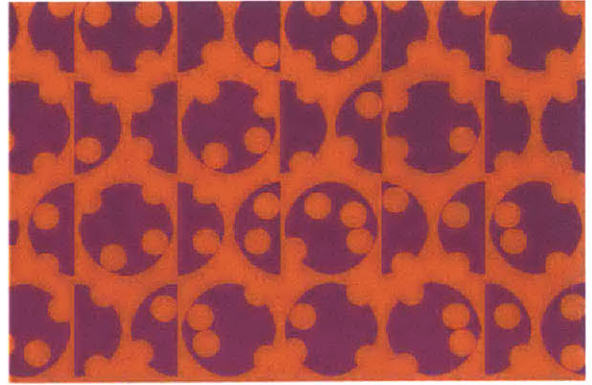
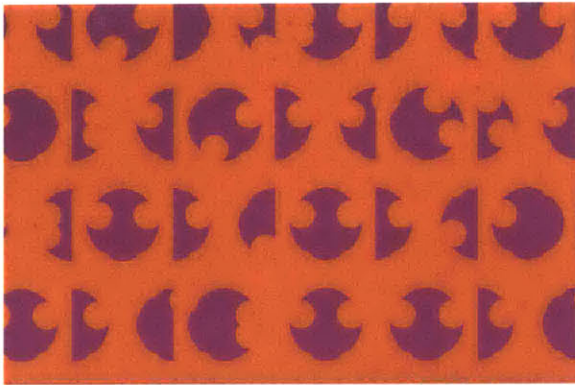
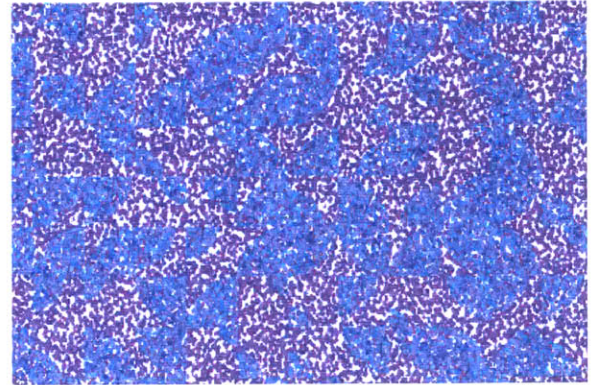
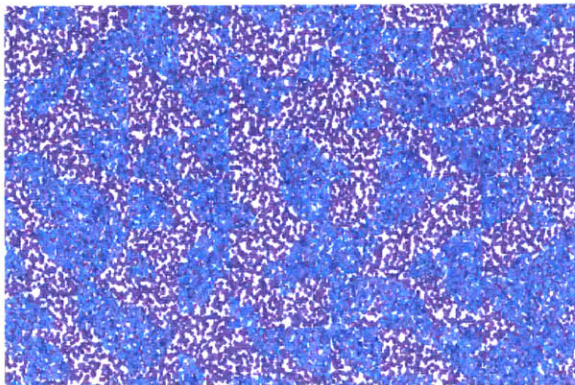
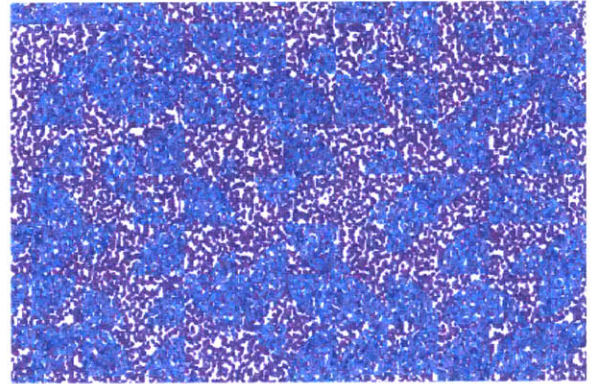
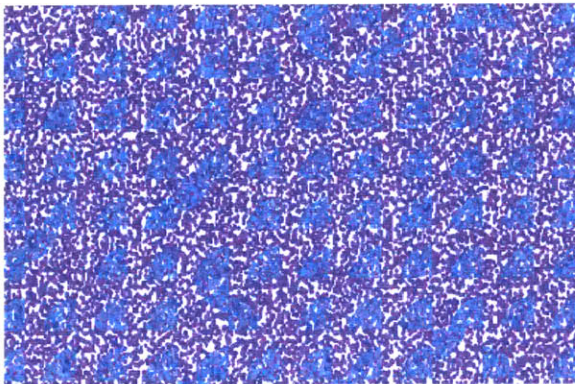


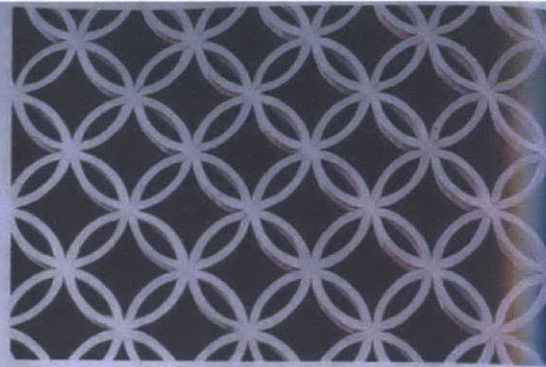
Fig 129 and 130: Snow Screen Pattern Motion Studies



OVERLAPPING CIRCLES

The overlapping circles pattern appeared as early as the eighth century, in the Shosoin, a building that is part of Todai-ji temple, in Nara.

The pattern is called *shippo* in Japanese, since it appears so often on cloisonné, or *shippo-yaki*. *Shippo* also means "seven treasures," which in ancient Asia referred to gold, silver, lapis lazuli, agate, pearl, coral, and crystal.



3



1

- 1 Overlapping circles (sandals)
- 2 Overlapping circles (bowl)
- 3 Overlapping circles
- 4 Overlapping circles (tray)
- 5 Overlapping circles
- 6 Overlapping circles
- 7 Overlapping circles
- 8 Overlapping circles (bowl)
- 9 Overlapping circles (*hibachi* hand warmer)
- 10 Overlapping circles (lidded tea bowl and saucer)



2



4

A series of studies using the motif of overlapping circles studies variations in the texture of the surface (Figs 132, 133). Layers of colored circles are used to create complex color interactions within the circles. A series of line studies of overlapping circles looks at contours and time (Figs 134, 135).

Fig 131: Page 116 Overlapping Circles (Snow, Wave, Pine Traditional Patterns in Japanese Design)

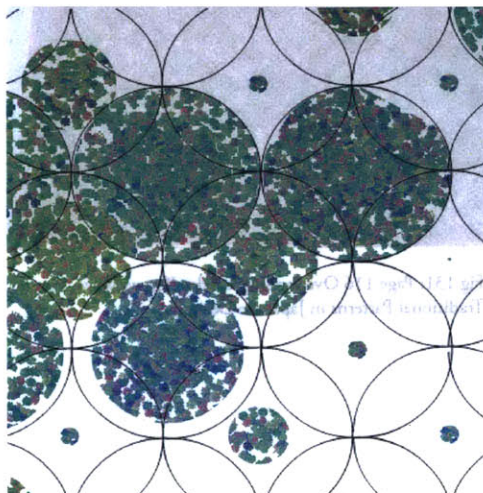
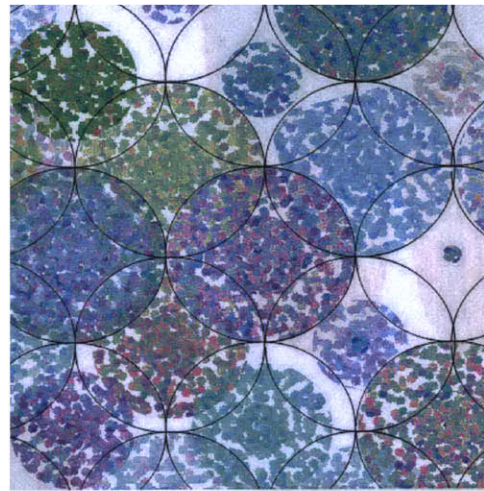
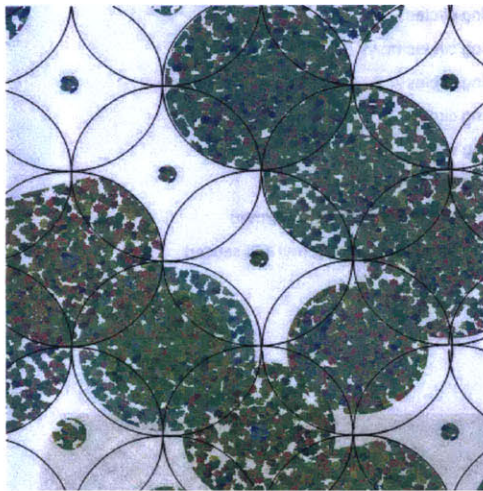
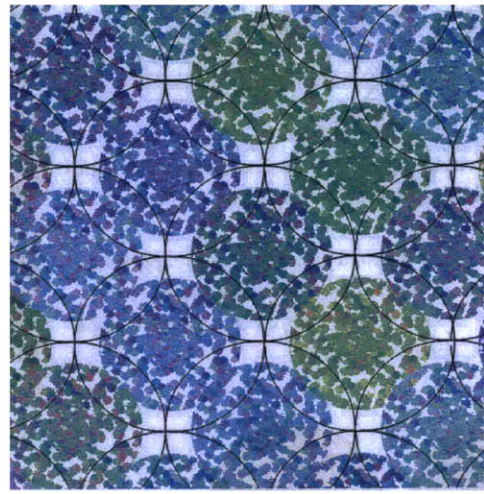
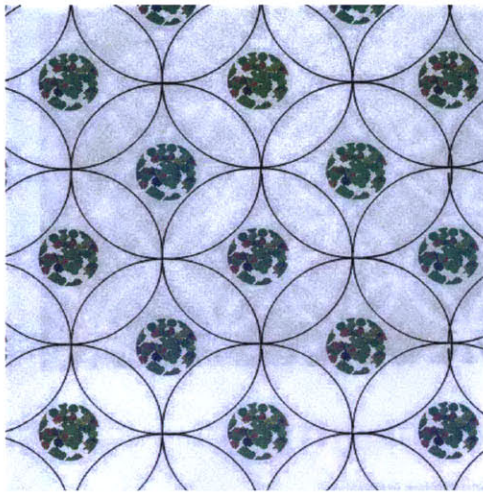


Fig 132: Snow Screen Pattern Motion Study

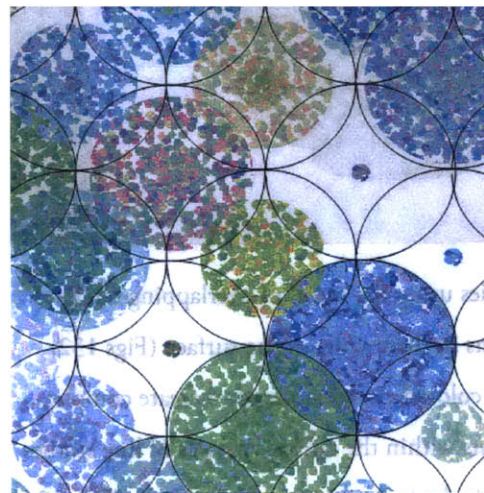


Fig 133: Snow Screen Pattern Motion Study

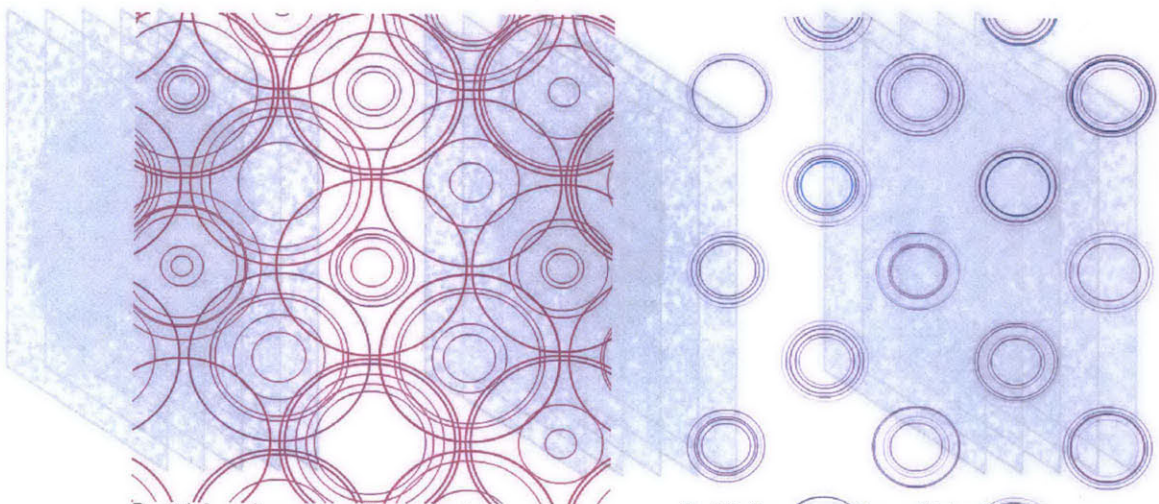
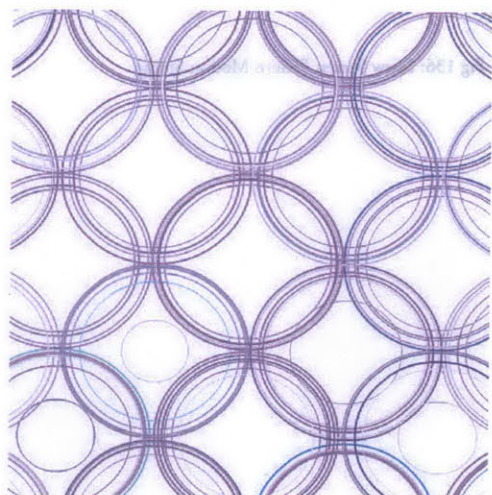
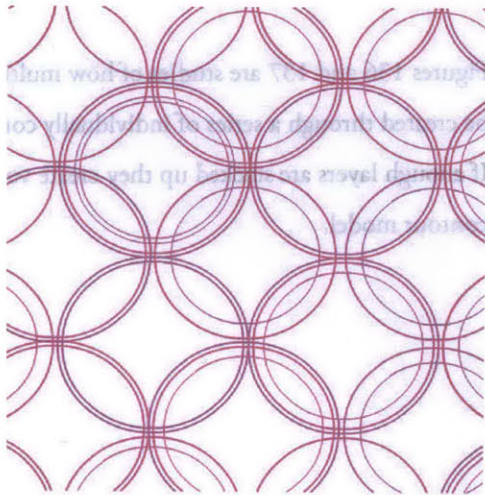
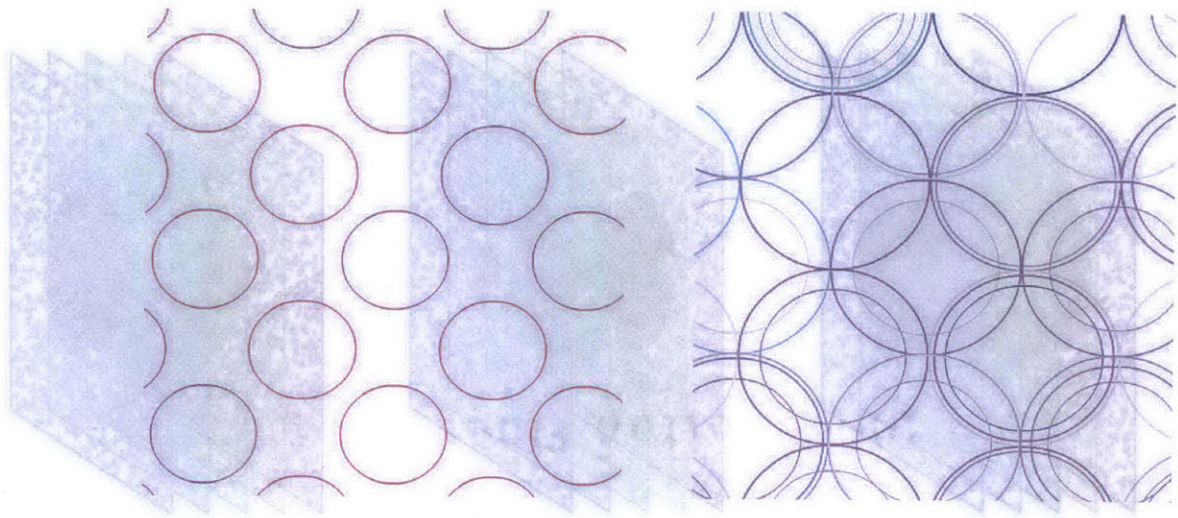


Fig 134: Snow Screen Pattern Motion Study

Fig 135: Snow Screen Pattern Motion Study

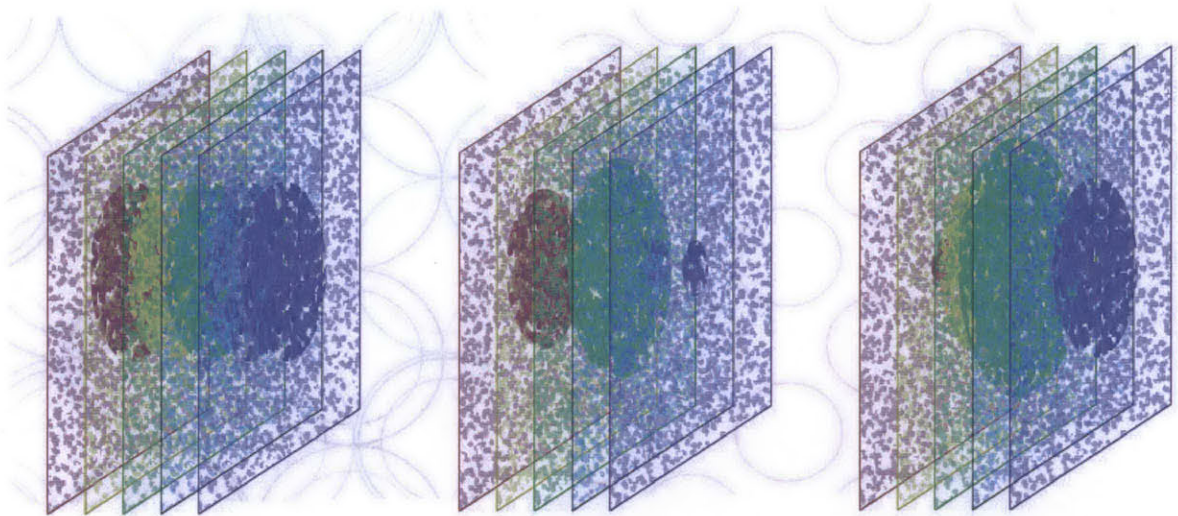


Fig 136: Snow Screen Pattern Motion Study

Figures 136 and 137 are studies of how multiple colors can be created through a series of individually controlled layers. If enough layers are stacked up they create volume like a contour model.

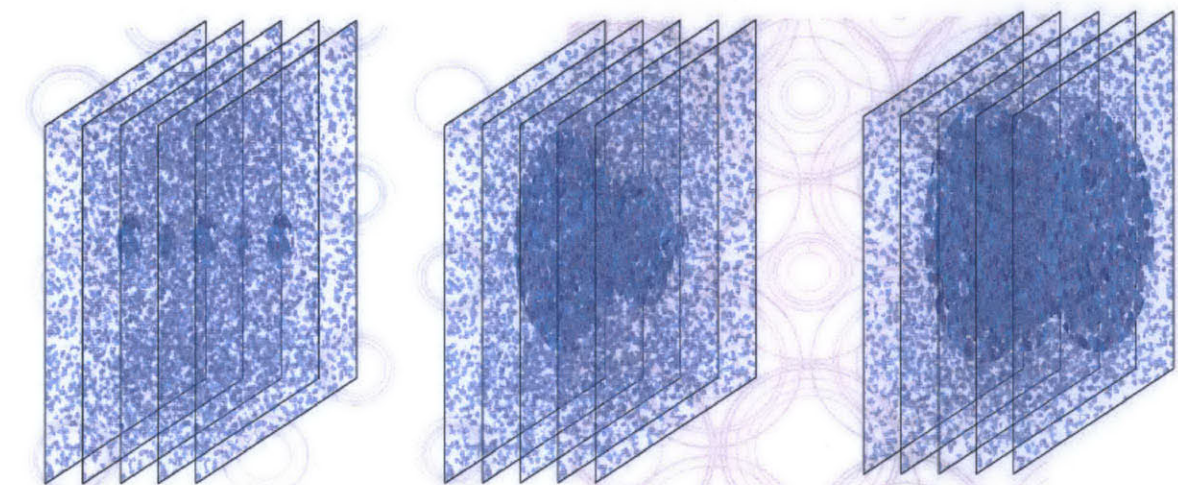
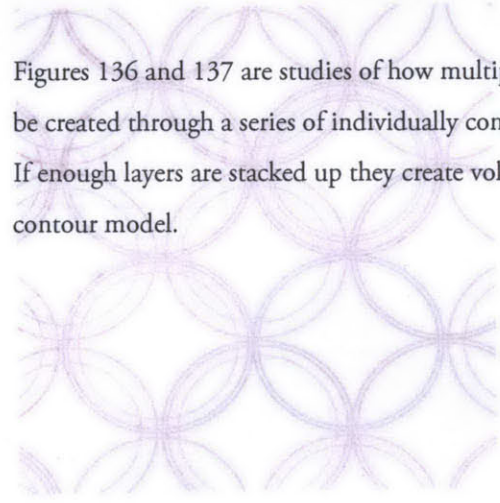
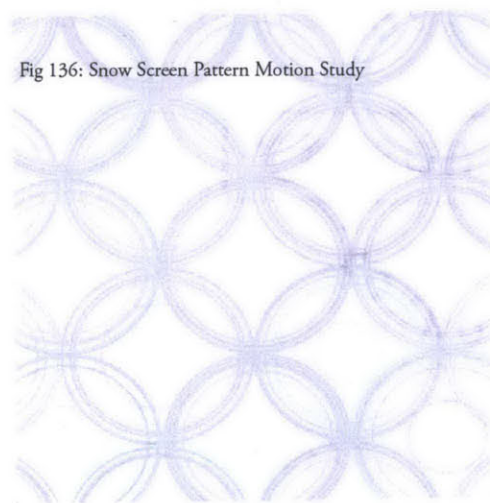
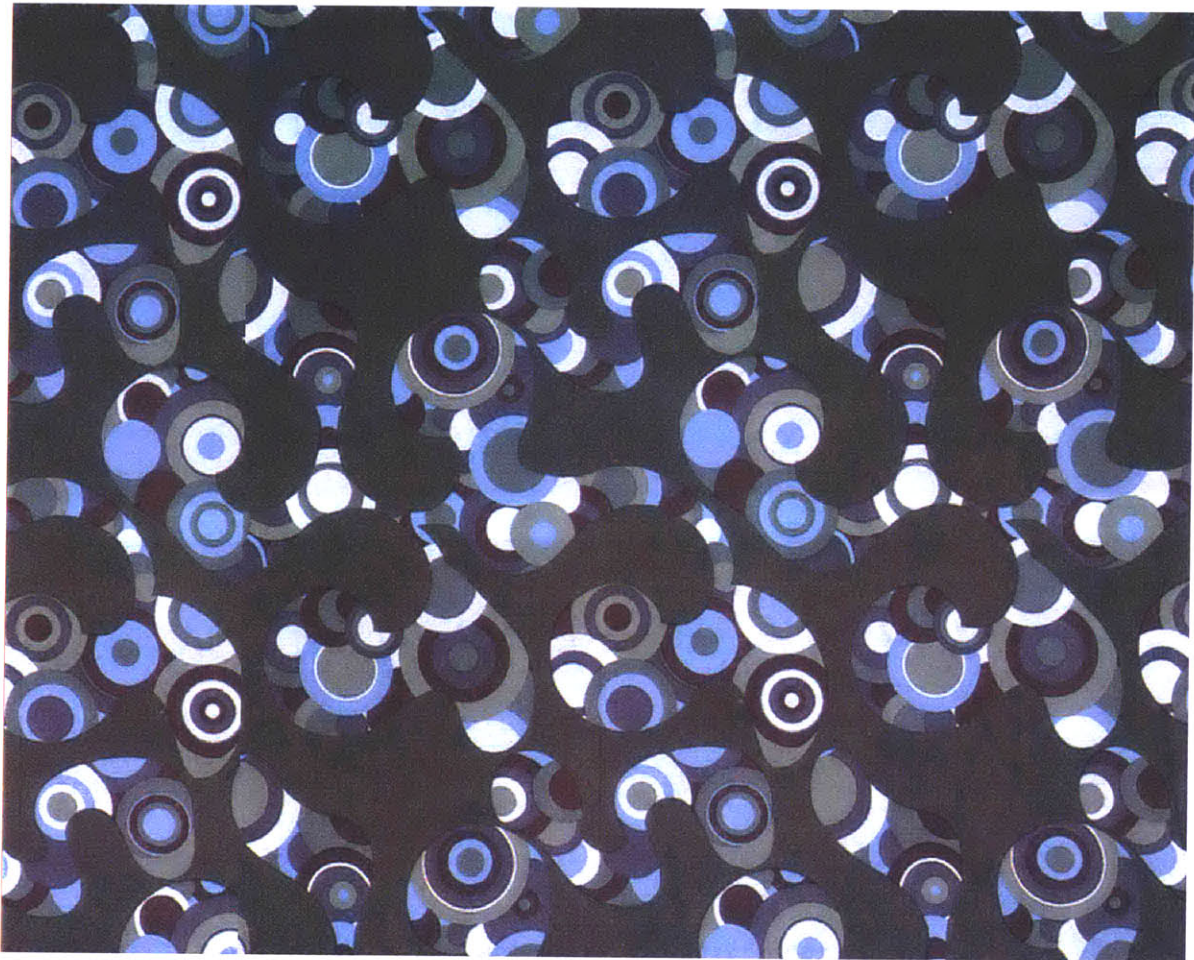


Fig 137: Snow Screen Pattern Motion Study



The pattern in Figure 138 was chosen because of its strong sense of layers to create a pattern informed by Figures 136 and 137. Figure 139 shows this pattern replicated as a two layered Snow Screen. Figure 140 presents this pattern on the Snow Screen in a sketch of a space to explain the changes in transparency on the surface.

Fig 138: Eddie Squires. "Delores" 1965. Screen-printed cotton furnishing fabric. (Twentieth Century Pattern Design, 148)

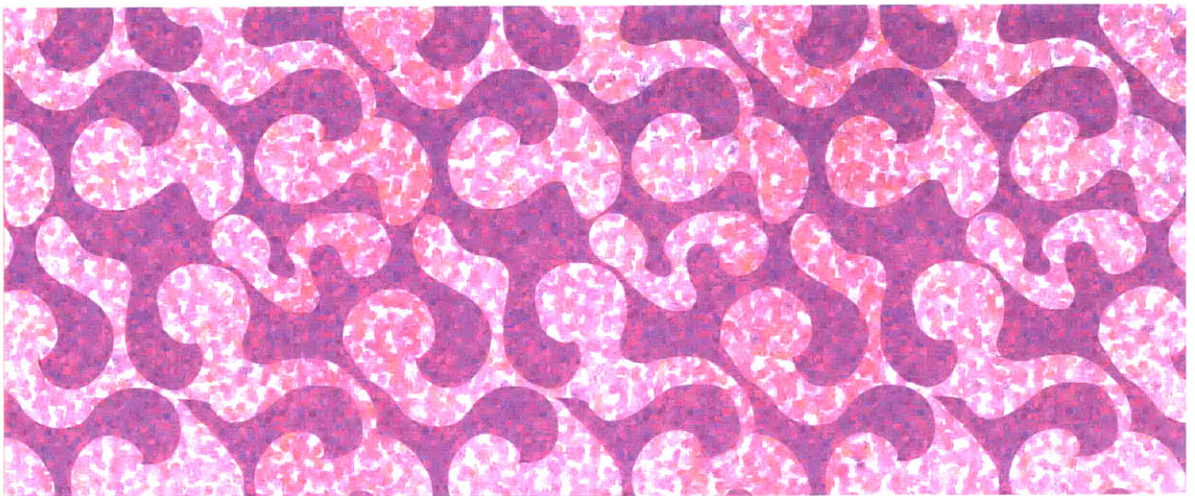
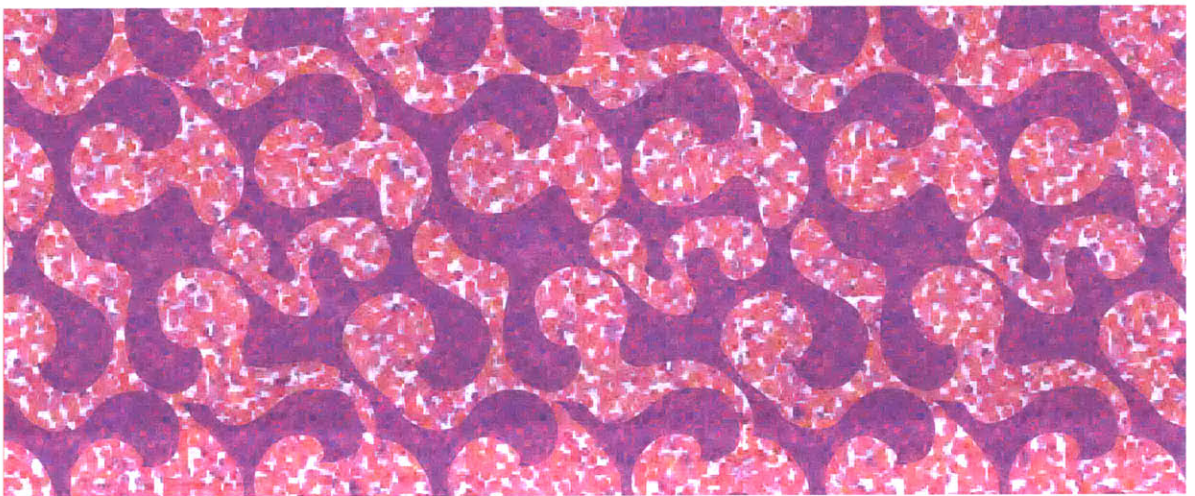
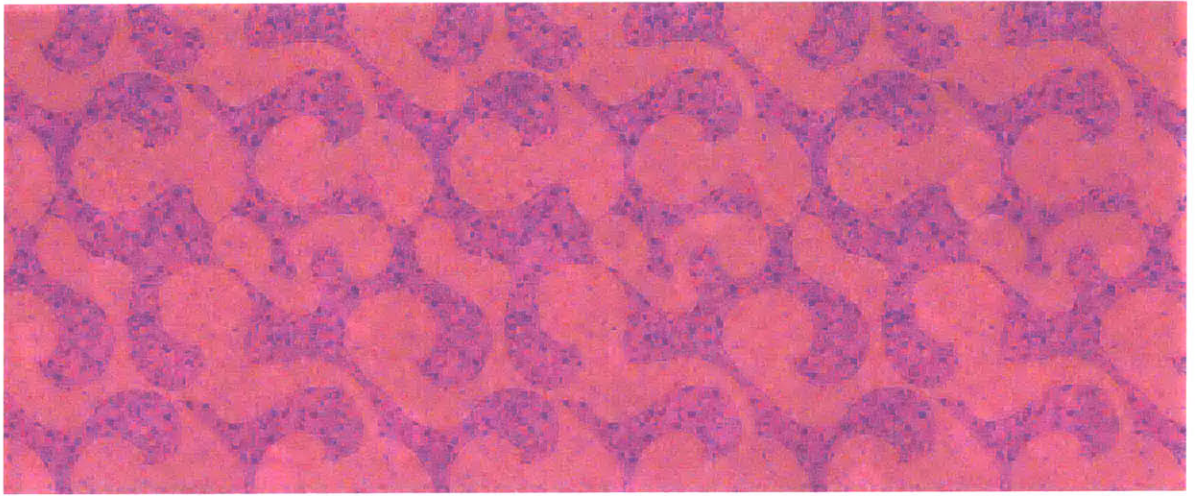


Fig 139: Snow Screen Pattern Motion Study



Fig 140 Snow Screen Pattern Motion Study



Fig 141: Bahia Brasile Convento di S. Francisco. Chiesa 1708-1713. Particolare dell'interno. (Barocco Latino Americano, 205)

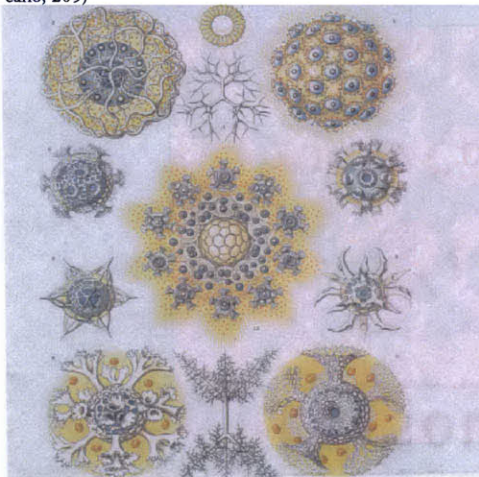


Fig 142: Ernst Haeckel. Polycyttaria. Vereins-Strahlunge. (Art Forms in Nature, 51)



Fig 143: Forcefield. On Website.

Conclusions

Where this research leaves the most work to be done is in the extension of these surfaces to interact with space. The motion graphic studies scratched the surface of human interactions and examined how to design surface patterns with motion but disregarded the spatial dimension. When the work engages architecture the ambiguity of virtual and real surface made so apparent by the physical nature of the surface complicates with the logic of the space. Figures 141, 142, and 143 show three distinct strategies of surface and space.

The possibilities of a surface with changing physical properties are relatively new. And so there is a limit to how designers are thinking about them, myself included. Figures 144, 145, and 146 suggest approaches to surface and motion. The Gordon Matta-Clark drawings reveals the importance of motion in the development of his spatial artworks. The drawings of David Wade show how surfaces in nature reveal the motion of how they were created.

Methodologies for the next steps of surface design are not clear. Design methods used by architects, such as physical can computer modeling interact with the 3rd dimension but are not so valuable for working with surface motion. Visual prototyping programs such as Flash are not so useful for investigating space.

Further investigation into this research will be through large prototypes, working at scales between interior design objects and architecture.

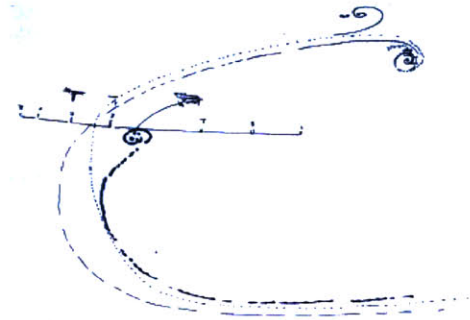


Fig 144: Gordon Matta-Clark. "Energy-Forms" 1964. (Forcefields, 138)

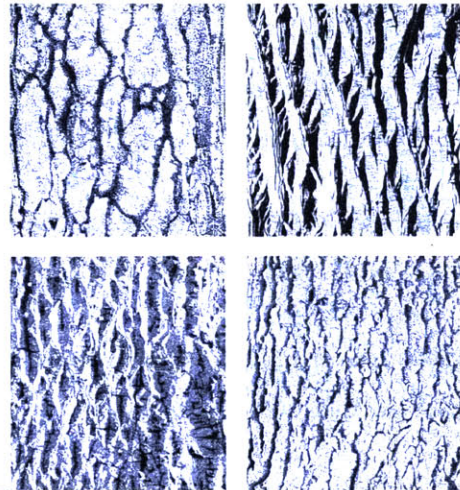


Fig 145: David Wade. Cracks in Elastic Materials. (Li: Dynamic Form in Nature, 25)

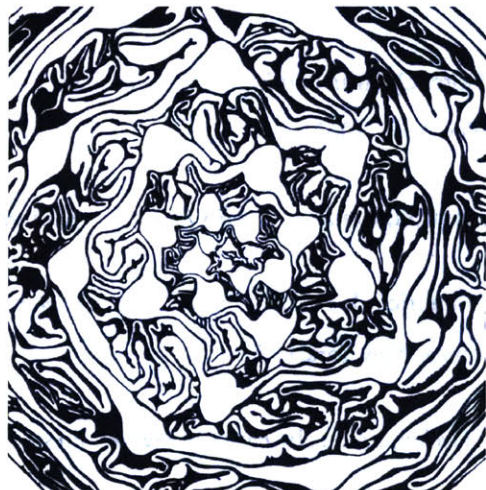


Fig 146: David Wade. Dynamic Spirality. (Li: Dynamic Form in Nature, 33)

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